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TANGANYIKA
UGANDA AND
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1940

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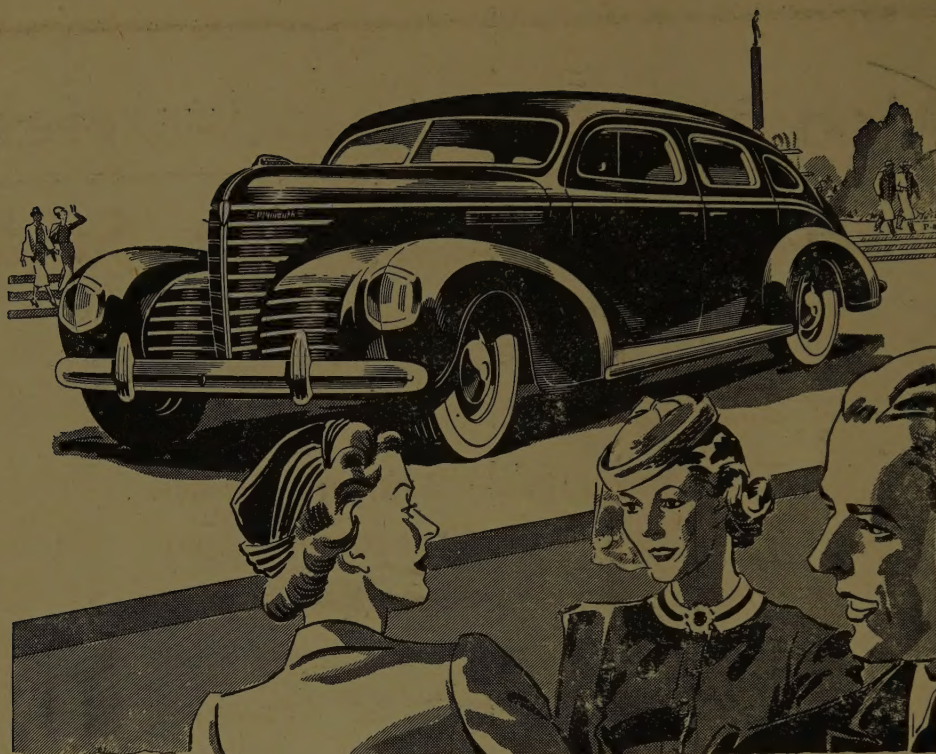
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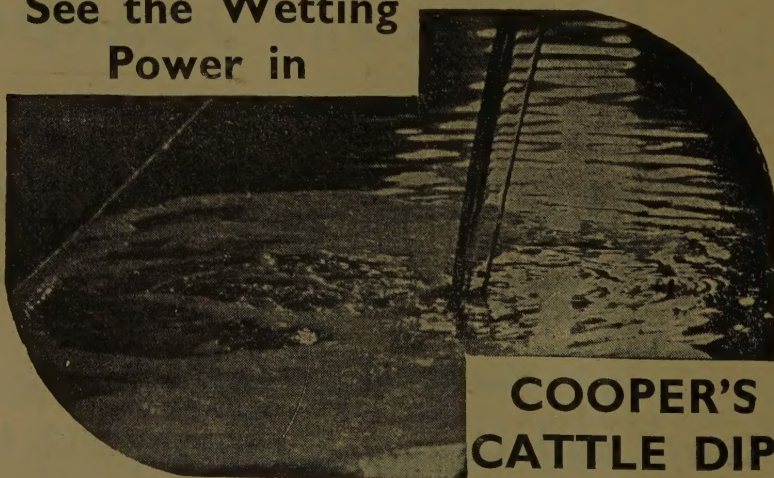
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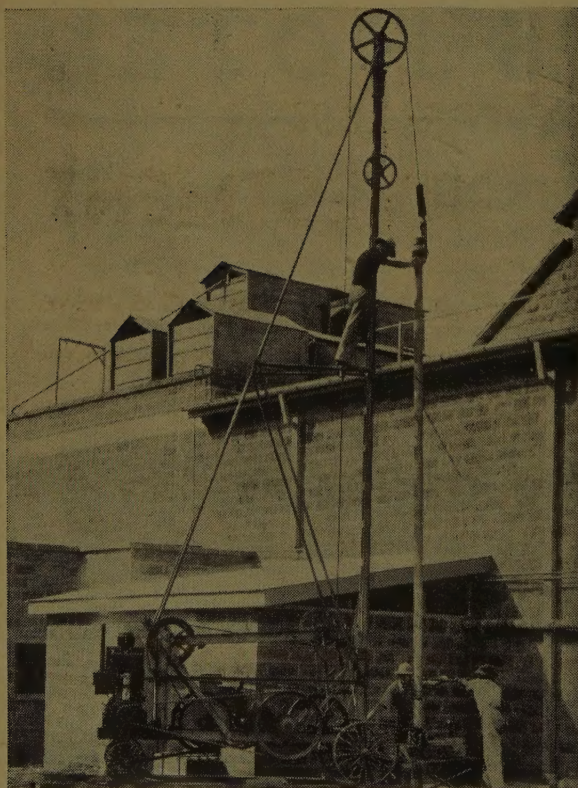
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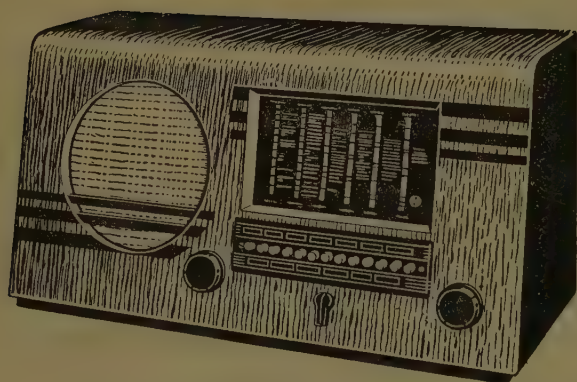
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CASSAVA RESEARCH

Of all the food crops grown by the native population of East Africa, cassava probably ranks as the most important. It is true that dieticians would discourage its use, for, as they point out, its roots lack both vitamins and minerals. But the plant is an efficient carbohydrate-producer, tolerant of a wide range of climates and soils, and is thus likely to retain its position as a basic food crop. In some areas cassava forms the staple food of the people; in others its function is more generally as a famine reserve. Here perhaps is cassava's greatest merit: it is a crop that can within limits be left on the ground and reaped at any time that it may be required.

In these circumstances it is natural that the improvement of the cassava crop should have been an important preoccupation of Agricultural Departments. It may be safely said that in almost every district of East Africa virus diseases constitute the chief factor limiting production. It is through the control of these diseases that important improvement is likely to come.

These virus diseases appear to be essentially African. A Mosaic disease was recognized as long ago as 1894 by German workers in the present Tanganyika Territory. Since then it has been reported from nearly every part of East, West and Central Africa and adjacent islands. Outside Africa there is a single record

from Java. The problem is therefore an African one, and one for African research to solve.

Study of these diseases has constituted for some years a part of the work of the Plant Pathology section of the East African Agricultural Research Station. The outcome has been to show that the problem is extremely complicated. Reports generally have written of "the mosaic disease," as if there was no more than a single disease involved. The Amani studies have shown that in East Africa there are two distinct diseases—Mosaic and Brown Streak; and that Mosaic is caused not by a single virus but by a group of presumably related strains.

Each virus can, in circumstances favourable to it, produce a profound effect on the plant, evidenced by a reduction in the yield of edible roots. The paper by Briant and Johns, published in this number of the Journal, provides ample evidence of the losses that Mosaic disease is causing in Zanzibar. Brown Streak is a more insidious disease in that it is less readily recognized than Mosaic; under some conditions its effect may be barely recognizable; under others it may kill the plant or reduce the roots to a rotting mass.

The paper by Briant and Johns summarizes several years' work by the Zanzibar Department of Agriculture. It reports important progress in the search for a high-yielding variety under the conditions of intense virus infection ruling in Zanzibar. It shows clearly the losses that can follow the planting of mosaic-diseased cuttings. Thus the mean yield of the Msitu variety, which heads the list of selections, fell from 14.3 lb. per plant to 2.3 lb. when originating from diseased cuttings. Such heavy losses can be counteracted to some extent by planting

only selected healthy cuttings; but selection is often difficult to carry out, and to teach the African to do it is a heavy task.

The desirable solution is evidently to find or produce a variety highly resistant to virus infection or at least to its ill-effects. Departments of Agriculture in other territories besides Zanzibar have been vigorously prosecuting the search. We need only refer to the extensive programme of seedling raising and testing in progress at the Morogoro Experiment Station; and the valuable discovery of the resistant Malindi variety at the Kibarani Experiment Station. Amani has contributed to this work in two ways: by the introduction through quarantine of cassava varieties from overseas, and by the production of hybrids of known parentage.

In a locality where virus infection has been intense for many years it must usually happen that selection for resistance has been continuously occurring without any scientific guidance. In choosing varieties for high yield the native cultivator has, probably unknowingly, selected mainly for resistance to virus diseases, or for tolerance to their effects. Cassava seeds freely, and self-sown seedlings commonly appear in plantations, so that the cultivator has had a large range of clones from which to make his choice. Consequently the search for resistance is most likely to succeed among established African varieties, and it was hardly to be expected that it would be found in varieties imported from outside Africa, where no such natural selection has occurred. The chance, however, that new genetical factors for resistance might be brought in was worth taking. In fact, of all the exotic varieties so far distributed from Amani, none has shown any particular merit in comparison with local selections. Importations from other parts of

Africa are in a different category; and in particular we may hope to benefit from the breeding work of Lloyd Williams in the Gold Coast. After a number of failures, due to the difficult journey from West Africa, a selection of these Gold Coast seedlings has now been established at Amani.

The second line of work in progress at Amani is the breeding of seedlings by controlled pollination. Particular interest attaches to the hybrids obtained from crossing cassava with other species of *Manihot*. The outcome of this development cannot be predicted; at present a considerable range of hybrid clones is under study and showing some promise.

Cassava improvement has thus been a co-operative enterprise in which territorial Departments of Agriculture and the East African Agricultural Research Station, Amani, have all taken a part. Plans are in preparation for similar co-operative investigations of other native food crops. The next few years should see large improvements in the position of the African cultivator.

H.H.S.

THE STORAGE OF FOODSTUFFS

As a natural complement to the drive for increased production there is the necessity for ensuring that what we do produce is not wasted by deterioration in store. The East African farmer, native as well as European, is not exposed to loss from some of the causes that plague the farmer in temperate countries; he will never see, as the English farmer has this year, the roots essential for the winter feed of his stock destroyed by frost in their clamps, however well constructed. On the other hand, throughout East Africa the temperatures are everywhere and unremittingly favourable to the biological processes that contribute to the

deterioration of stored foodstuffs. Ill-effects range from the taints imparted by micro-organisms, which may impair palatability and prejudice sale before they very seriously diminish food values, to the grievous damage done by weevils and beetles and the gross depredations of the rat.

To Africa the technique of large-scale storage, which can practically be taken over wholesale from the temperate countries, is hardly as important as an adequate system of storage for the isolated hamlet, the single native family and the single farm. For such users, cheapness of construction is a paramount consideration, and this generally implies the use of local materials.

With the object of pooling the available information on the subject, a summary, printed elsewhere in this number, has been compiled by the Agricultural Advisers to the Secretary of State. It deals with methods for both large-scale and small-scale storage, stressing throughout that good results are dependent not only on construction of the stores but also on the maintenance of cleanliness and on the good condition of the product when it is carried in. The importance of cleanliness in the stores was also emphasized by Mr. W. V. Harris, in his "Notes on Food Storage" printed in the March number of the Journal.

Several African peoples have evolved useful types of storage for themselves, some of which have been described in the Journal, and it is noteworthy that certain crop varieties have been distinguished by their growers as possessed of better storage qualities than others. Here is yet another desideratum to add to the many that must be borne in mind by those concerned with the improvement of the food supplies of the African.

R.E.M.

CASSAVA INVESTIGATIONS IN ZANZIBAR

By A. K. Briant, M.A. (Camb.), Dip. Agric. (Camb.), A.I.C.T.A., and Robert Johns, N.D.A., C.D.A., A.I.C.T.A., Department of Agriculture, Zanzibar

INTRODUCTION

Cassava is by far the most important of the food crops grown in Zanzibar, and it occupies an area of several thousand acres. Cassava and cassava products are neither imported into nor exported from the Protectorate, and the crop is grown entirely for the production of roots for human or animal consumption.

This article discusses various matters appertaining to the cultivation of the crop and reports the investigations that have been carried out at Kizimbani Experiment Station during the last six years.

CULTIVATION

Cassava is grown on all types of soils and under very varying conditions. As a rule, wherever soil and other conditions are most suitable for the production of cloves, clove trees have been planted and remain the principal crop. The second most important crop, coco-nuts, has been planted very extensively, sometimes within, but chiefly on the borders of or outside, the best clove areas. Food crops, including cassava, therefore usually take third place, and are generally planted by the poorer classes on any available patches of open land or, where these are scarce, in the numerous open canopied areas actually within the clove or coco-nut fields. Shifting cultivation is very common.

Cassava is planted nearly all the year round, but chiefly just before or during the *masika* or *vuli* rains. Stem cuttings, about eight inches long, are usually planted on ridges about five feet wide, although flat planting is the rule in Pemba. During the first few months of its growth, the crop is often interplanted

with catch crops, such as maize, cowpeas or sweet potatoes. The standard of cultivation is generally extremely simple, with no manuring and little or no after-cultivation. The roots are ready for harvesting in about eight to fifteen months, depending on the variety and conditions, but actually they are harvested much later or earlier, according to the time when food or cash is required. Yields are very variable, as may be seen from Tables I and IV.

PESTS AND DISEASES

The chief insect pests of cassava in Zanzibar are white flies, thrips and termites. The direct damage caused by these pests is very slight, but white flies are important indirectly because they transmit cassava virus diseases.

The incidence of mosaic disease is particularly high in all districts, and it is estimated that an average of at least 60 to 75 per cent of the plants in Zanzibar are infected.

USES

Most of the roots are used for human consumption, and when eaten fresh are generally boiled in coco-nut juice or roasted. Roots not required immediately are peeled, split and dried in the sun, after which they may be stored for two or three months. When required for eating, the dried roots are placed in a mortar and pounded into a flour, which is usually boiled into a sticky thick porridge. The raw roots of the sweeter varieties possess a distinct nutty flavour, and are frequently eaten by labourers while working in the field. They are also, especially the varieties of inferior flavour, used as a cattle food.

VARIETIES AND TYPES

There are very many varieties in Zanzibar which differ greatly in their morphological characters, the time taken to mature, the resistance and tolerance to mosaic diseases, and in the yield and quality of their roots. In different parts of the Protectorate a single variety may be known by several different names. Conversely, because some varieties produce seed very freely in the field, new varieties originate naturally in the field, and any seedlings resembling well-known varieties may be mistaken for them.

From the cultivator's point of view, the chief aim is to obtain a large yield of good quality roots. The comparison of yield and quality of different varieties is complicated by differences in their maturation periods, and in their behaviour under varying soil and climatic conditions. Most varieties grown are of the sweet type, but bitter types do exist, and sweet types are said to become bitter, and slightly bitter types more bitter, when grown in certain localities. The poorer red soils in Zanzibar are said to induce bitterness, and roots from certain villages or those with red soil adhering to them do not meet with ready sale in the markets.

PREVIOUS INVESTIGATIONS

Cassava investigations were commenced at Kizimbani Experiment Station in 1933, when four local varieties, Kifumfum, Msitu, Kapilima and Kuriami, were included in a variety trial for comparison with regard to yield and mosaic infection. In 1934, twenty-six varieties were imported from the East African Agricultural Research Station at Amani and four from Java. In 1935 the collection of local varieties was increased, and each year since 1936 other varieties have been obtained from Amani.

During the period 1933-39 one hundred varieties have been received and grown

under observation. Many of these have been discarded after only one or two years' trial on account of their poor yield or because of the bitterness of their roots. The rejection of varieties for bitterness is justified because Kizimbani is known to produce sweet roots and is not one of those localities where bitterness is said to be accentuated.

In 1937 the effect of mosaic diseases on the yield of individual plants of three different varieties at Kizimbani was reported on by Tidbury [1]. He found that wholly diseased plants yielded significantly less than partly diseased or healthy plants (at 1 per cent significance), but that there was no significant difference between the yields of partly diseased and healthy plants. He suggested that it might be advantageous to rogue and replace by disease-free cuttings all plants showing mosaic symptoms during the first few months of growth.

It has been noticed that some varieties, that had produced large yields during the first one or two years at Kizimbani, later deteriorated rapidly; these have since been discarded. This is no doubt partly due to the fact that cuttings of new varieties are usually received in a mosaic-disease-free condition, and that the yields deteriorate as the plants become increasingly affected by the local strains of the mosaic viruses. Varieties have not yet been discarded on account of external signs of susceptibility to virus diseases without some additional reason.

There are undoubtedly differences in the susceptibility of different varieties of cassava to mosaic disease, and under a given set of conditions it may be assumed that there is a tendency for each variety to acquire a certain degree of infection. As infection influences yield, the plant populations of each variety included in yield trials should be infected with mosaic diseases to a degree approaching as nearly

as possible the normal degree of infection for that particular variety. For this reason the planting material used in the trials described below was selected at random from available mixed supplies. In making cuttings there is a tendency for labourers to discard diseased cuttings by rejecting very thin stems, and, as healthy plants usually grow larger and stronger than diseased ones, and therefore produce more cuttings, the proportion of healthy to diseased cuttings obtained is larger than the proportion of healthy to diseased plants in the original parent population. The proportion of healthy plants produced by these cuttings is, however, soon reduced by secondary infection in the field.

In 1937 an experiment consisting of two randomized blocks of half an acre each was laid down to compare the yields of eight different varieties. The results indicated (at 5 per cent significance) that the local variety Msitu was significantly better with regard to yield than the varieties Kajayeye, Binti Athman, F. 279, Mshele, Kijiti, and Mbarika. The experiment just failed to show a significant difference in yield between the two best varieties, Msitu and F. 100, although their yields differed greatly as follows:—

Msitu: 2,227 lb., equivalent to 7.95 tons per acre.

F. 100: 1,547 lb., equivalent to 5.07 tons per acre.

The experiments carried out in the season 1938-39, the conclusions to be drawn from them, and suggestions for future work, are described below.

1938-39 VARIETY TRIAL

This trial consisted of an 8 x 8 latin square. Each plot was 20 ft. x 30 ft. in size, and contained four banks 5 ft. wide, on each of which were planted ten cuttings, 3 ft. apart. An extra space of 5 ft. was left along the banks between adjacent

plots. The cuttings were planted on 24th March, 1938, and blanks were supplied as necessary during the first two months of growth. A complete manurial dressing was given to all plots and the roots were harvested from 10th to 13th March, 1939.

Table I gives the varieties included in the trial, their origins, the total yields obtained for each variety, and the calculated yields per acre.

TABLE I

VARIETY	Origin	Total yield	Calculated yield per acre
		Lb.	Tons
Msitu	Zanzibar ..	2,217	8.98
Mpezaze	Amani ..	2,019	8.18
Kru	Gold Coast via Amani ..	1,968	7.97
F.100	Java ..	1,492	6.04
F.64	Java ..	1,115	4.52
E.20	Java ..	943	3.82
Sareso	W.A. via Amani ..	726	2.94
Pamba Mangubu ..	Amani ..	554	2.24

The statistical analysis of the yield figures shows (at 5 per cent significance) that a difference in the total yields of any two varieties which is greater than 318.2 lb. is significant. The varieties Msitu, Mpezaze and Kru are therefore significantly heavier yielders than the remaining five varieties.

1938-39 MOSAIC-RESISTANCE TRIAL

This experiment was laid down to investigate problems concerning resistance to mosaic disease by growing varieties under conditions designed to increase the chances of infection.

A half-acre field was ridged with banks 4 ft. apart, and on every third ridge, beginning with the first, cuttings of the variety Mbarika were planted. The cuttings of this variety were almost without exception badly infected with mosaic disease.

The eighteen varieties included in the trial were replicated in six blocks, each of which consisted of two adjacent ridges, 90 yards long, between the hedges of

Mbarika. Each ridge was divided into nine plots, each containing ten cuttings of a variety, planted one yard apart. The position of the varieties in each block was not completely randomized, but the arrangement of the hedges ensured that every plant undergoing trial was growing in close proximity to mosaic-infected plants.

As in the variety trial, the cuttings were selected at random with no selection to obtain mosaic-disease-free material. The plots were planted on 28th March, 1938, and from June onwards monthly records were taken of the approximate degree of infection of each individual plant in every plot. The plots were reaped from 12th to 17th March, 1939, and the weights of cassava obtained from each plant were recorded individually. The total weights obtained from each variety and the calculated yields per acre are given in Table II.

TABLE II

VARIETY	Total weight	Calculated yield per acre	Order of yield	Order of yield in variety trial
	<i>Lb.</i>	<i>Tons</i>		
Msitu	472	12.75	1	1
Mpezaze	461	12.4	2	2
Kru	443	11.9	3	3
Ankrah	405	10.9	4	—
F.279	390	10.5	5	—
Kilele cha mfuu	360	9.7	6	—
F.100	355	9.6	7	4
Binti Athman ..	325	8.8	8	—
Mahole	279	7.5	9	—
Kajayeye	267	7.2	10	—
E.20	254	6.75	11	6
F.64	244	6.6	12	5
Kijiti	243	6.6	13	—
White Stick ..	242	6.5	14	—
Mbega	197	5.3	15	—
Sareso	166	4.5	16	7
Kimtongani ..	162	4.1	17	—
Pamba Mangubu	149	4.0	18	8

Although the lay-out of the blocks does not permit the results of the experiments to be treated statistically, the similarity between these yields and those obtained in the 1938-39 variety trial is remarkable. The yields obtained in this experiment were from 1.42 to 1.77 times the yields

obtained in the variety trial, due perhaps partly to differences in soil fertility and partly to the different spacing of the ridges. The order of the eight varieties, when arranged according to their yields, is exactly the same in both experiments, except that E. 20 and F. 64 displace one another. Such close agreement indicates that, while the experimental error of the yields in the mosaic-resistance trial cannot be accurately estimated, it is likely to be very low, and the yields obtained for the eighteen different varieties are probably extremely typical of the bearing capacities of the varieties under such conditions. Acting on this assumption, all planting material of the eleven poorest yielding varieties was destroyed and these varieties will not appear in future trials.

THE INFLUENCE OF MOSAIC DISEASE ON YIELD

The monthly observations with regard to mosaic infection and the final determination of individual plant yields have permitted the individual plant yields of each variety to be grouped into three health classes, viz:—

Group I.—Includes plants that showed no signs of infection with mosaic disease at any time during their growth.

Group II.—Includes plants that appeared to be healthy two months after planting, but which subsequently became infected (secondary infection).

Group III.—Includes plants that showed signs of infection from the time of development of their first leaves—the infection probably developing from infected cuttings (primary infection).

A chart tabulating the number of plants in each of these health classes, arranged according to the yield of the individual plant, is given as Table III. The figures for each variety are given separately, and the varieties are arranged in the order of their total yields.

TABLE III
CASSAVA VARIETY—MOSAIC RESISTANCE TRIAL 1938-9 FREQUENCY CHART

Yield in Lb.	Msitu			Mpezaze			Kru			Ankrah			F.279			Kilele cha Mfuu		
	H.	S.I.	P.I.	H.	S.I.	P.I.	H.	S.I.	P.I.	H.	S.I.	P.I.	H.	S.I.	P.I.	H.	S.I.	P.I.
26	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
25	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
24	1	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—
23	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—
22	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
21	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
20	—	3	—	—	—	—	—	—	—	1	—	—	1	—	—	—	1	—
19	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
18	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2	—	—
17	—	—	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—
16	1	1	—	—	—	—	1	1	—	—	—	—	1	—	—	1	—	—
15	1	—	—	1	—	—	—	—	—	2	—	—	1	—	—	1	—	—
14	—	1	—	1	—	—	2	3	—	—	—	—	—	—	—	—	—	—
13	2	1	—	2	—	—	3	2	—	1	—	—	—	—	—	1	—	—
12	—	1	—	—	1	—	3	1	—	1	—	—	1	—	—	2	—	1
11	2	2	—	3	2	—	3	1	—	1	—	2	2	1	—	—	1	—
10	2	1	—	3	—	—	—	3	—	3	—	2	2	2	—	2	1	1
9	—	2	1	4	3	—	1	3	—	—	3	3	6	—	—	—	—	—
8	—	1	—	7	1	—	2	3	—	1	—	3	3	—	—	—	—	—
7	3	1	—	5	1	1	1	—	—	—	—	2	4	—	3	2	2	1
6	—	1	1	5	2	—	1	—	—	1	—	2	1	1	1	2	2	1
5	—	2	—	—	2	—	4	1	—	—	1	4	3	3	3	2	1	2
4	—	1	1	2	—	—	—	1	—	—	—	4	—	3	1	—	—	—
3	—	1	3	—	1	2	1	1	—	—	—	8	2	1	3	1	1	6
2	—	—	4	1	—	1	3	2	—	—	—	6	—	—	3	2	4	2
1	—	—	5	—	—	5	—	—	2	—	—	4	—	—	4	1	—	4
0	—	—	6	—	—	1	—	—	4	—	—	4	—	—	2	1	1	4
	15	19	21	20	13	10	25	22	6	8	8	44	27	11	20	18	17	22
	55			59			54			60			58			57		

TABLE III—contd.
CASSAVA VARIETY—MOSAIC RESISTANCE TRIAL 1938-9 FREQUENCY CHART

Yield in Lb.	F.100			Binti Athman			Mshale			Kajayeye			E.20			F.64		
	H.	S.I.	P.I.	H.	S.I.	P.I.	H.	S.I.	P.I.	H.	S.I.	P.I.	H.	S.I.	P.I.	H.	S.I.	P.I.
26	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
25	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
24	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
23	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
22	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
21	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
20	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
19	—	—	—	1	—	—	—	—	—	1	—	—	—	—	—	—	—	—
18	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—
17	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
16	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—
15	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—
14	2	2	—	1	—	—	1	—	—	—	—	—	—	—	—	—	—	1
13	—	1	—	1	—	—	1	—	—	1	—	—	—	—	1	—	—	—
12	1	—	—	1	1	—	1	—	—	2	—	—	—	—	1	—	—	—
11	2	2	1	1	—	—	1	1	—	3	—	—	—	—	3	—	—	1
10	—	1	1	2	—	—	2	—	—	1	1	—	—	—	—	—	—	2
9	—	4	1	4	2	—	1	2	—	1	1	—	—	—	2	—	—	2
8	1	1	—	3	2	—	2	1	—	2	1	1	—	—	—	—	—	3
7	1	2	—	1	1	—	1	—	—	—	—	—	—	—	1	—	—	4
6	2	—	—	1	1	—	—	—	—	1	1	—	—	—	—	—	—	3
5	1	1	2	6	3	—	1	—	—	1	1	—	—	—	4	—	—	6
4	—	—	4	3	2	—	3	1	2	3	—	1	—	—	8	—	1	3
3	—	—	5	1	2	1	3	1	3	1	—	5	—	—	12	—	—	6
2	—	—	6	—	—	—	1	—	3	3	2	6	—	—	10	—	—	3
1	—	—	9	3	2	2	1	—	11	—	1	8	—	—	4	—	—	11
0	—	—	5	1	—	9	—	—	2	—	—	8	—	—	8	—	—	9
	10	14	36	30	15	13	21	6	24	16	10	31	—	—	59	—	1	55
	60			58			51			57			59			56		

TABLE III—contd.
CASSAVA VARIETY—MOSAIC RESISTANCE TRIAL 1938-9 FREQUENCY CHART

Yield in Lb.	Kijiti			White Stick			Mbega			Sareso			Kintongani			Pamba Mangubu		
	H.	S.I.	P.I.	H.	S.I.	P.I.	H.	S.I.	P.I.	H.	S.I.	P.I.	H.	S.I.	P.I.	H.	S.I.	P.I.
26	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
25	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
24	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
23	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
22	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
21	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
20	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
19	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
18	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—
17	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
16	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
15	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—
14	—	—	1	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—
13	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—
12	—	—	—	1	—	—	—	1	—	—	—	—	1	—	—	—	—	—
11	1	—	1	—	2	—	—	—	—	1	—	—	2	1	—	—	—	—
10	—	—	4	—	—	—	—	1	—	—	—	—	—	—	—	—	—	1
9	—	1	1	—	—	1	—	—	3	—	—	1	—	—	—	—	—	—
8	—	—	—	1	1	2	—	—	—	1	—	—	—	—	—	—	—	2
7	—	1	2	1	1	2	1	3	2	—	—	—	—	2	—	—	—	—
6	—	1	3	—	—	2	—	—	4	—	—	2	—	—	—	—	—	5
5	1	—	3	1	1	7	—	1	4	—	2	3	—	1	2	—	—	1
4	—	1	3	1	—	3	—	—	3	—	—	3	—	1	1	—	—	9
3	1	—	11	—	—	7	—	—	3	—	1	4	—	—	2	1	8	—
2	—	1	7	—	—	8	—	—	6	—	1	6	—	1	5	—	—	6
1	—	—	—	—	2	4	—	—	8	—	1	9	2	2	7	—	—	2
0	—	—	4	—	—	12	—	1	16	—	1	21	1	1	12	—	—	12
	3	5	40	5	7	48	1	6	50	—	10	49	6	11	29	—	1	46
	48			60			57			59			46			47		

NOTES.—H=Healthy plants.
S.I.=Plants with secondary infection.
P.I.=Plants grown from diseased cuttings, primary infection.
Figures indicate number of plants.

TABLE IV

VARIETY	GROUP I No INFECTION			GROUP II SECONDARY INFECTION			GROUP III PRIMARY INFECTION			TOTAL GROUPS I, II AND III		
	Total weight	No. of plants	Average weight per plant	Total weight	No. of plants	Average weight per plant	Total weight	No. of plants	Average weight per plant	Total weight	No. of plants	Average weight per plant
	lb.		lb.	lb.		lb.	lb.		lb.	lb.		lb.
Msitu ..	215	15	14.3	209	19	11.0	48	21	2.3	472	55	8.6
Mpezaze ..	334	36	9.3	105	13	7.9	23	10	2.3	461	59	7.8
Kru ..	228	25	9.1	212	22	9.6	3	6	0.5	443	53	8.4
Ankrah ..	90	8	11.3	100	8	12.6	214	44	4.9	405	60	6.8
F.279 ..	249	27	9.2	71	11	6.5	70	20	3.5	390	58	6.7
Kilele cha Mfiu ..	145	18	8.1	136	17	8.0	79	22	3.6	360	57	6.3
F.100 ..	98	10	9.8	142	14	10.2	115	36	3.2	355	60	5.9
Binti Athman ..	221	30	7.4	88	15	5.9	15	13	1.2	325	58	5.6
Mshelo ..	175	21	8.3	46	6	7.6	58	24	2.4	279	51	5.5
Kajayeve ..	116	16	7.2	80	10	8.0	71	31	2.2	267	57	4.7
E.20 ..	—	—	—	—	—	—	254	59	4.3	254	59	4.3
F.64 ..	—	—	—	4	1	4.0	240	55	4.4	244	56	4.4
Kijiti ..	20	3	6.7	30	5	6.0	193	40	4.8	243	48	5.1
White Stick ..	38	5	7.6	45	7	6.5	158	48	3.3	242	60	4.0
Mbega ..	7	1	7.0	37	6	6.1	153	50	3.1	197	57	3.5
Sareso ..	—	—	—	70	10	7.0	96	49	2.0	166	59	3.0
Kintongani ..	38	6	6.3	70	11	6.4	44	29	1.5	152	46	3.3
Pamba Man- gubu ..	—	—	—	3	1	3.2	146	46	3.2	149	47	3.2

In Table IV the number of plants of each variety in each of the three groups is shown, together with the total and average weights of their roots.

The examination of these tables reveals that:—

1. The average yield of healthy plants is considerably higher than that of plants of the same variety with primary infection. The difference is very marked for the three heaviest yielding varieties, the figures for Msitu being 14.3 and 2.3 respectively. This observation is extremely important, and indicates that yields may be considerably increased by planting only healthy cuttings and by replacing young diseased plants by healthy cuttings as soon as infection is apparent.

2. The difference between the yields of healthy plants and plants showing secondary infection is not very pronounced. This is partly because secondary infection may affect only a small portion of a plant, and partly because infection may occur too late in the season to affect the yield seriously.

3. With few exceptions, e.g. Ankrah and Kru, the higher the total yield given by a particular variety, the lower was the number of plants that showed symptoms of primary infection.

4. Primary infection reduced the average yield of single plants of all varieties to a very low level, from 0.5 lb. per plant for Kru to 4.9 lb. for Ankrah. The variation recorded bears no relation to the total yield of the different varieties, and indicates that the varieties vary in their tolerance to infection. The variation is, however, sufficiently great to affect the relative position of some varieties, e.g. Ankrah and Kru, in the order of yield. This is responsible for some of the exceptions referred to in paragraph 3.

SEASONAL EFFECT ON RATE OF SPREAD OF MOSAIC DISEASE

Storey and Nichols [2], experimenting with the variety Mbarika at Kiwanda, near Amani, failed to detect any variation in the susceptibility of individual plants with age, but they found that the probability of infection varied considerably with the season of the year, being greatest from February to May and least from August to October. The rainfall is reported to be fairly evenly distributed throughout the year, with a peak in May and minima in January and July.

In the Kizimbani mosaic-resistance trial, all plants were examined individually at the middle of each month and records were taken of the approximate severity of the disease in all infected plants. The number of new infections recorded each month is given in Table V.

TABLE V

Monthly Period	New infections	New infections as per cent of remaining healthy plants	Rainfall Kizimbani, 16th of month to 15th of next
April-May	—	—	13.04
May-June	22	5.5	10.44
June-July	18	4.8	0.87
July-Aug.	6	1.7	1.35
Aug.-Sept.	3	0.9	0.61
Sept.-Oct.	29	8.3	2.43
Oct.-Nov.	27	8.5	13.13
Nov.-Dec.	21	7.2	15.11
Dec.-Jan.	8	2.9	8.86
Jan.-Feb.	8	3.0	0.33
Feb.-March	34	13.3	0.13

In the third column the number of infections recorded is given as a percentage of the number of healthy plants at the beginning of each monthly period concerned. These figures are not strictly comparable, because the original healthy plants consisted of varying numbers of plants of different varieties, probably varying in resistance to the disease, and because, as more plants became infected, the sources of further infection increased. Nevertheless, there appears to be a

definite relation between infection and rainfall, the figures for which are given in the fourth column.

Storey and Nichols [3] state that under greenhouse conditions at Amani symptoms of mosaic appear 12 to 20 days after the disease has been transmitted by white flies. Assuming that the period in Zanzibar is about two weeks, monthly observations should result in the recording of a new infection between two and six weeks after its actual occurrence. Infection figures for any particular month, therefore, are more likely to bear a relation to the climatic conditions during the previous month than to those during the month under consideration. It must also be borne in mind that adverse conditions affecting the population of white flies might influence the number of infections taking place for a period of several months. It appears therefore that the small numbers of infections which were recorded during the periods July to September and December to January may have been due to the climatic conditions existing during the rainy periods March to June and October to December respectively.

1938-39 OBSERVATION PLOTS

The following thirteen new varieties, which were received at Kizimbani for trial in a mosaic-disease-free condition from Amani, were grown in observation plots in order to obtain an approximate estimate of their yield and to multiply promising varieties to obtain sufficient planting material for larger trials:—

Malindi,	Nkwekwe,
Basiorao,	Nodewide,
Mangi,	Numbu,
Binti Minsi,	Seseri,
Korogwe,	Sofe,
Mukabulu,	Wallace.
Nakasoga,	

Four of these varieties, namely Basiorao, Mangi, Binti Minsi, and Numbu, were discarded at the time of harvest because of their low yields.

MULTIPLICATION PLOTS

In March, 1938, when the 1937-38 variety trial was reaped, it was realized that Msitu was an extremely promising variety, and all planting material not required for trials was planted in order to propagate the variety for distribution. Plants infected with mosaic disease were continually rogued, and although many plants were cut back, to provide cuttings for extending the area, over 20,000 mosaic-disease-free cuttings were distributed to the public within a year. The results of the 1938-39 variety and mosaic-resistance trials have again indicated that Msitu is the best yielding variety of those which have yet undergone trials, and its propagation for distribution is being continued.

FUTURE PROGRAMME

One of the most important conclusions to be drawn from the above experiments is that primary infection reduces the average yield of all varieties to a very low level, whereas the effects of secondary infection are not very pronounced. This means that the planting of healthy cuttings, including cuttings of recently imported varieties, will not during the first year indicate the final yields of the varieties under field conditions. The introduction and testing of new varieties, and the distribution of the best variety or varieties to the public, are now to be carried out in four stages, as follows:—

First Stage.—New varieties will be exposed to infection with local viruses by growing them in multiplication plots in close proximity to plants already infected with mosaic disease. At the time of harvesting any definitely unpromising varieties will be discarded.

Second Stage.—The varieties not discarded in the first stage, together with a variety of known standard, will be included in a mosaic-resistance trial similar to that described above, but consisting of fully randomized blocks. The yields of the varieties will be statistically compared and unsatisfactory ones will be discarded.

Third Stage.—The varieties that have proved to be the best in the second stage of the previous year will be compared in a variety trial with standard varieties consisting of the two or three best ones known. The standard varieties will usually be those which proved to be the best in the variety trial of the previous year, and they will remain the standards until their records have been surpassed.

Fourth Stage.—This stage consists in the multiplication of the best variety or varieties known for distribution to the public. All plants showing signs of mosaic disease will be continually eradicated from the field so as to distribute disease-free cuttings, which should demonstrate well the yielding capacity of the variety and the value of planting healthy material.

ACKNOWLEDGMENTS

The writers are greatly indebted to Mr. R. W. R. Miller, Director of Agriculture, Zanzibar, for many useful suggestions and criticisms during the progress of this work, and also to Dr. H. H. Storey, of the Amani Research Station, for helpful advice and information.

SUMMARY

Over one hundred cassava varieties have now been grown at Kizimbani. The best yielding of the sweet varieties so far tested are Msitu (local variety), Mpezaze (from Amani), and Kru (from Gold Coast via Amani). The variety Msitu is being propagated on a large scale for public distribution. Information has been obtained on the effect of primary and secondary infection with mosaic disease on the yield of individual plants of eighteen varieties. Results indicate that primary infection seriously reduces yield, but that secondary infection is of less importance. Infected cuttings should therefore not be planted.

There appears to be correlation between the occurrence of new cases of secondary infection and past climatic conditions.

Experimental work is being continued.

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A theory founded upon a knowledge of all the facts often becomes a law; if based upon a sufficient number of facts it may

form a working hypothesis; while if too few facts are available it cannot be other than an indiscretion.

Dr. W. A. Linnell.

NOTES ON THE PLANTING AND MAINTENANCE OF CITRUS TREES

By J. C. Eyre, B.Sc. (Agric.) (Stell.), D.I.C., Department of Agriculture,
Tanganyika Territory

SELECTION OF A SITE

Altitude.—Altitude has a considerable effect on citrus trees. Grape fruit and limes will not grow well at high altitudes, while the European type of lemon does better in a cooler climate. Oranges can be grown almost anywhere, but they do best in a mild climate under a high rainfall.

Water.—If running water is available, choose a site which can be irrigated; otherwise choose a low-lying area which is well drained. A citrus tree does not shed its leaves during the dry season; therefore it requires a certain amount of moisture throughout the year; but citrus will not grow well on badly drained land.

Soil.—Do not plant in very light, sandy soils, gravelly soils, or heavy clay. A light deep loam is the ideal. Avoid planting along the sides of roads and paths.

Wind.—Citrus trees will not flourish if they are exposed to high winds; this is particularly important where water or rainfall is meagre.

A good site is often found along the banks of a river where alluvial soil has been deposited. If there are any trees along the river they can be used as your windbreak, but ensure that the water table is not too high.

Almost invariably it will be found that the best sites are already occupied by cultivation. For the first few years there would be no harm in allowing intercropping with other crops, provided they are not planted too close to the trees.

PLANTING

Nursery Trees.—Trees are usually sent out from the nurseries ready for planting; they have been headed back to about

three and a half feet in height and the roots have been trimmed. The leaves are removed, because the trees travel and transplant much better in this condition. When you receive the trees plant them as soon as possible, and do not expose them to the sun more than is absolutely necessary. If the trees are to come by train or lorry, remember to tell the stationmaster and the lorry driver that the package must be protected and kept in the shade.

Time to Plant.—It is best to arrange to plant citrus trees with the advent of the main rains, but in districts where there are short rains the trees can be planted then, provided that water is available to keep the trees alive during the subsequent dry period.

Holes for Planting.—Make holes 20 ft. to 24 ft. apart. The holes should be 2 ft. across and 2 ft. deep. The full 2 ft. of width should continue to the bottom of the hole. Put the top soil aside and return it to the hole first when the trees are planted.

Planting.—Do not plant the trees too deeply; the first of the crown roots should be just visible after the tree has settled down.

When planting spread the roots out in their natural position and firmly tamp down the soil; then give the trees a good watering. The trees and the soil will sink as they settle down, so give the tree a pull up to the right level after a week, and again tamp down the soil.

Another method of planting which is especially suitable in areas of high rainfall is to make a mound of earth and plant the tree on this; it will ensure that the tree does not suffer from "wet feet."

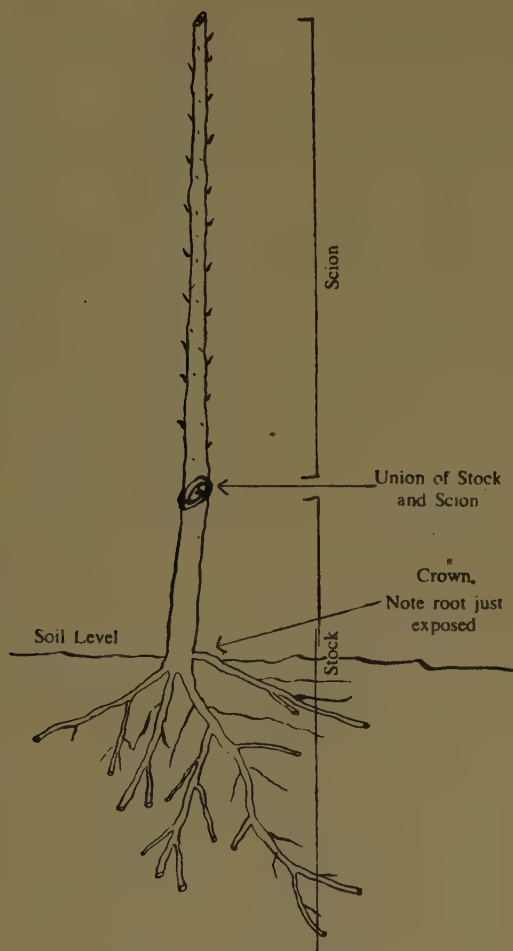


Fig. 1—How to Plant.

Manure.—Good earth can be used for filling the holes, but do not use fresh manure or fertilizers; they would have much the same effect on the trees as neat whisky on a starving teetotaller.

Shade.—Provide the young trees with some shade or alternatively whitewash the stems or cover them with thatching grass until the trees are well established.

Development of the Main Branches.—All the shoots on the stock (the bottom part) should be rubbed off as soon as they appear, and when the young shoots on the scion (the top part of the tree) have grown out about 8 inches choose three to

six of them for the main scaffold branches and rub off all the others. They should be well spaced up and down the scion and around the scion. Do not select any within $1\frac{1}{2}$ ft. of the ground.

When the scaffold branches are two to three feet in length cut them back to eight inches in length. Beyond the removal of surplus shoots on the main stem and on the scion no further pruning will be necessary for some time. Some nurserymen send out their trees with the main scaffold branches already formed and cut back.

Remove any fruits which are borne in the first or second years. You will get a small crop in the third year, under favourable conditions.

MAINTENANCE

Pruning.—Orange, lime, grape fruit and tangerine trees do not require regular pruning beyond the removal of sucker growth which arises from the main stem and the cutting out of dead and diseased branches or branches which are tending to become too dominant or are obviously misplaced. It is occasionally necessary to remove a branch from the centre of the tree to admit sun and light. When pruning, cut right back to the branch, and do not leave a stub; the cleaner the cut the quicker it will heal. Paint the pruning wounds with any oil paint available. Pruning should not be done when growth is active.

Do not keep cutting back the main lower branches as nearly everyone does in Tanganyika.

Lemon trees require regular pruning, but this should not be too drastic. The long vigorous shoots which arise from the top branches and from the main stem should be cut back and other small branches should be thinned out and shortened occasionally.



Fig. 2—Desirable Shape.



Fig. 3—Undesirable Shape.

Manuring.—The trees will appreciate some manure. Rotted *boma* manure or compost, with plenty of wood ash, is suitable. Citrus trees do not like an acid sour soil.

Cultivation.—Keep the land well cultivated and free from weeds and grass, but

see that the roots and trunks of the trees are not injured by careless or too deep cultivation.

Irrigation.—Give the trees all the water you can get for them, but ensure that the soil does not become waterlogged and sour.

Windbreaks.—Protect the trees from the prevailing winds, especially the dry season winds; if necessary, plant a wind-break, but see that it does not overshadow the trees.

Pests and Diseases.—Citrus trees are subject to numerous different pests and diseases, but Tanganyika is remarkably free from the more serious of them. If the trees appear to be suffering badly from diseases or such pests as scale, the cause is probably bad treatment, neglect, or unsuitable conditions.

GENERAL

Citrus trees should receive just as much constant attention and care as any other permanent crop, and especially when the trees are young. Results will be disappointing if the trees are forgotten until they are supposed to be bearing fruit, as by that time the white ants will have destroyed them or they will be miserable small bushes carrying nothing more than a few dead twigs and yellow leaves.

Among social insects we have seen that the community is virtually a vast proletariat of sterile working classes. Each individual member, uninfluenced either by rules or by legislation, labours with the utmost diligence; its toils last the day long, and even night by no means always brings respite. Individual aspirations, comfort, or pleasure find no place in such an economy, yet there is neither dissension nor strife. Individual lives are of little

account, there are so many; each is intimately merged into that of the community of which it is a part, and is unhesitatingly sacrificed in its service whenever occasion demands. We may pause and take comfort in the reflection that a social system of this kind is unattainable by any coercive or repressive manifestations on the part of the most ruthless human dictatorship.

(But this was written in 1931.—Ed.)

A. D. Imms in *Social Behaviour in Insects*.

TROUT IN KENYA COLONY

PART II—THE RAINBOW TROUT

By Hugh Copley, Assistant Game Warden, Kenya Colony

EARLY HISTORY

It is believed that the first importation of rainbow ova was made from South Africa by the late Commander Barry in 1910. The offspring from these were placed in the Amboni and the Nairobi Rivers. The main importation of ova took place in 1919 and 1921, and as a result rainbow trout were spread all over the Colony. Since then many other importations have been made, the last being in 1924. There is now a total of 1,666 miles of water containing rainbow trout in the Colony.

DESCRIPTION OF THE RAINBOW TROUT RIVERS

The rainbow trout streams differ from the brown trout streams in that there are no deep basins on the low moorland from which they can draw a supply of water. Hence there is a far greater rise and fall in their water levels and local storms cause a very quick and generally a very dirty spate. (Fig. 12 gives the yearly rainfall charts of two important rainbow stream areas; Fig. 13 shows a diagrammatic view of the course of a typical stream.) These rainbow streams are situated in groups. There is the Mount Kenya group, in which the rivers have their beginnings near the peak, from which they radiate. There is the Western Aberdare group, of which all the rivers have their sources in the forest at an altitude of 9,000 to 9,500 ft. The rivers of the Mount Elgon group also rise in the high forest areas. Lastly, there are the Kericho rivers, which again have their sources in the main range, in forest not higher than 9,000 ft.

On Mount Kenya four rivers have their sources from glaciers, but generally

speaking in none of the typical rivers is the temperature below 52° F.; and in the accessible stretches it is from 60° to 65° F., rising in the hot weather to 68° to 72° and over. This is not the highest temperature at which rainbow trout will live and thrive, as will be shown in a later section.

As stated before, the higher waters are in the forest, and at present protected from the destructive methods of mankind. From the forest line downwards the surrounding land is generally open grazing or farm land, and the river there is subject to violent flooding; such floods, owing to erosion, often carry large quantities of mud.

Until the present wasteful methods of native agriculture cease, trouble from this cause will always be experienced. It must be admitted that the trouble is by no means only met with in native reserves for it also exists on lands in European districts. It might be mentioned that few riparian owners take the slightest steps to preserve or improve their fishing, despite its potential value. Such a situation makes for difficulties when there is public and private fishing adjoining. The results of improvement work on the public water may be completely nullified by lack of care on private water.

Geology

Mount Elgon.—This is an old mountain of the late Pliocene, which has been subjected to great denudation, and certain rivers have cut their paths through the rim of the crater. Although the geology is not quite clear, the opinion may be ventured that the mountain consists of a great overflow of nephelinite over basalt.

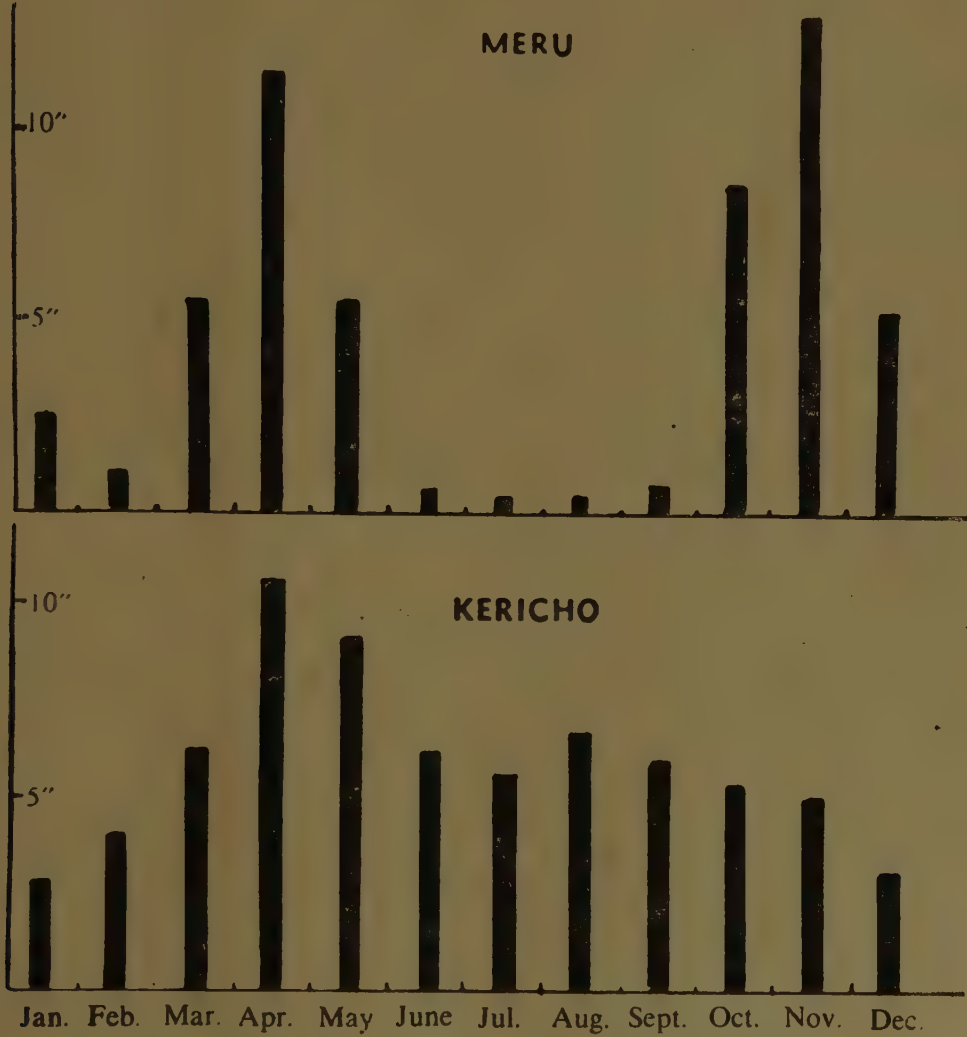


FIG. 12—YEARLY RAINFALLS IN INCHES: RAINBOW TROUT RIVERS

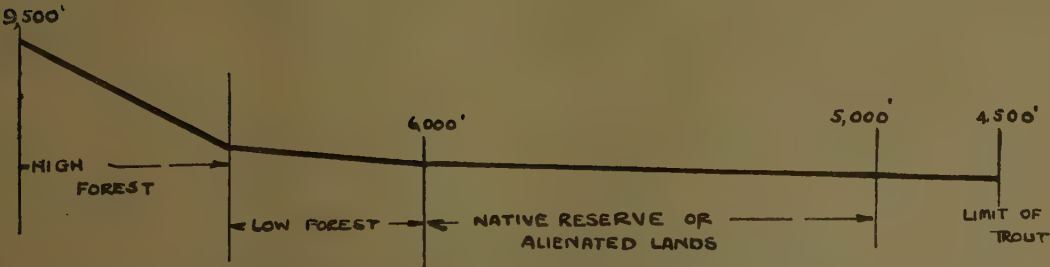


FIG. 13—DIAGRAMMATIC VIEW OF THE COURSE OF A TYPICAL RAINBOW TROUT STREAM

Mount Kenya.—This mountain consists of a single peak which is the core of the volcano exposed by weathering. Below this an alpine moorland surrounds the central plug, and lower still there is a vast dome covered by bamboo and forest. Some of the main trout streams have their sources in the bamboo, but the majority rise in the high moorlands at 14,000 to 15,000 ft. A very few draw their supply of water from the glaciers on the central plug. This is an olivine-bearing nepheline-syenite (Gregory); below it there is a zone of agglomerate, volcanic tuff and lava. Gregory has proposed the name "kenyte" for the lavas of Mount Kenya. These lavas are based on phonolite and also on basic basalt. Olivine-basalt dykes cut across the kentyte and the phonolite, and these doubtless form the numerous high falls on the upper reaches of all the rivers. As on the Aberdare range, some rivers may have cut through the kentyte and the phonolite down to the basalt.

The Western Side of the Aberdare Range.—The great majority of the streams of the western slopes of the Aberdare range flow over trachytic and rhyolitic tuffs, often cutting down very deeply into this agglomerate. This seems to be based on phonolitoid-kentyte, and these again on basalt. All the rivers give an acid reaction from pH 5.4 to 6.8.

Kericho District.—Although little is known of the geology of this district, the opinion may be ventured that all the rocks over which the streams flow are volcanic and consist of nephelinites and phonolitic trachytes. It will be seen that all the rivers have their courses over rocks of a volcanic origin and that their pH readings may be expected to give an acid reaction.

TEMPERATURES

With the exception of the headwaters of the Sirimon, Liki, Sagana, and North Mara Rivers, the temperatures average

from 50° to 60° F. Down-stream, in the accessible parts, they are from 60° to 72° F. Rainbow trout thrive at such temperatures, which indeed are not the highest at which they have been taken. A number of large rainbow trout, all over 10 lb. and in excellent condition, were caught at an altitude of 4,000 ft. in water with an average midday temperature of 82° F. There are also rainbow trout in excellent condition in Lake Naivasha, which also reaches these high temperatures. That the rainbow trout has adapted itself to a warmer water environment seems to be a fact; examples can be quoted where they are successfully spawning in water of a temperature of 56° F.

CHEMICAL FEATURES

The upper stretches of all rainbow rivers are fast, with occasional pools, and well-oxygenated water. The big fish keep to the pools during the daytime but move to the shallows towards the late evening; they remain there throughout the night, and return to the pools about dawn. Smaller fish find harbourage behind boulders in the fast water throughout the twenty-four hours. In the native reserves and the alienated lands there are long deep stretches in which the big rainbow trout remain all day, but they go to the heads and the tails of these stretches about dusk.

A great number of pH readings have been made in many rivers giving results from 5.6 to 8.3; yet in all these waters rainbow trout flourish and in most they are breeding too fast for the food supply.

ABSTRACTION OF WATER

This has been severe on some rivers; but the problem is being handled in the manner described in Part I. It is most important to have no obstruction on rainbow trout rivers, for these fish will run down any trickle of water at any time of

the year; so that if facilities are provided to enable the fish to migrate the upper overstocked stretches are relieved of some of their surplus population.

POLLUTION

Pollution from coffee pulping factories during low water affects the rainbow on the lower waters, and attempts have been made and are always being made to alleviate this.

Two cases have occurred where the liquid from cattle dips had been passed into a river. In both cases numerous deaths occurred, but the affected parts of the river completely recovered after the next rains.

BIOTIC FACTORS

Scale Readings.—The following are scale readings of rainbow trout taken from various rivers:—

SAIBEI RIVER			
Weight	..	..	2½ lb.
Sex	..	..	Female
Length	..	..	18"
Girth	..	..	10½"

Growth Rates :

Year			3 yrs. 6 mths.
1st	2nd	3rd	
6"	12"	16"	18"

Spawned once at 2 years, once at 3 years.

KIPSONENDI RIVER			
Weight	..	..	7 lb. 6 oz.
Sex	..	..	Male
Length	..	..	29"
Girth	..	..	Unknown

Growth Rates :

Year			
1st	2nd	3rd	4th
8½"	16"	23"	27"

Fish had gone back badly and was near the end of its life.

MELAWA RIVER

Weight	..	..	4½ lb.
Sex	..	..	Female
Length	..	..	22"
Girth	..	..	11½"

Growth Rates :

1st Year	2nd Year	2½ Years
10½"	16"	22"

Partial spawning at 12". Partial spawning at 14"
Complete spawning at 16½". Partial spawning at 20½"

The first and the third are examples of typical rainbow trout. It will be seen that they are big eaters and fast growers, coming to their prime in three years. The second is an example of a fish well past the prime of life. So far no rainbow trout has come to hand over 4½ years of age.

Growth rates are sometimes simply astounding; the record rainbow trout of 12 lb. 11 oz. was 3 years and 10 months old and had spawned four times.

Retention of Ova.—This has occurred in isolated individuals, but to nothing like the extent found with the large brown trout. This again points to the assumption that rainbow trout are more adaptable than the brown trout to a warm water environment.

Breeding Seasons.—There is no well-defined breeding season. Fish seem to breed all the year round, and scale readings have shown that many fish shed their ova or milt twice a year regularly. Sometimes there is only a partial shedding of the ova, and the rest is extruded later on in the year.

The sex ratios of rainbow trout present an interesting problem. A careful count on one river showed 67 per cent of males to 33 per cent of females; another river gave 58 per cent males to 42 per cent

females, and it seems very probable that in all our rivers there is a preponderance of males. An analysis of anglers' catches, however, has a most contradictory result, since in a creel there are often twice or even three times as many females as males. I am uncertain as to the reason for such discrepancy. It may be that females are more voracious, or less selective in their feeding habits, or both. But there are many things that we do not know about trout, and it is possible that there is some other and different explanation of the matter.

Enemies.—These have been fully discussed in Part I, and the same remarks apply to the rainbow trout. The spotted eel (*Anguilla labiata*) is only found in the lower reaches of a few of the rainbow trout streams that flow off the eastern slopes of Mount Kenya and a few that flow into the Athi and Sagana Rivers from the Aberdare range. They are not found in any other of the rainbow rivers.

Diseases.—The remarks on brown trout apply equally well to the rainbow.

FOOD SUPPLIES IN THE RIVER

When dealing with the brown trout, various sections of the river were taken, and it was pointed out that the virgin waters had an ample supply of under-water life, and that Perlidae (stone-flies) and Trichoptera (caddis-flies) were the first to suffer as trout food. The same holds good of the rainbow trout rivers, and the following is a sample of the food on one of our well-known rainbow rivers, which yields a bag of 3,000 fish per annum.

(a) THIBA RIVER, ALTITUDE 9,200 FT. (Bamboo Areas)

		Per cent
Ephemeroptera ..	Fam. Ecdyonuridae ..	76.4
" ..	" Leptophlebiidae ..	11.8
" ..	" Baetidae ..	5.8
Diptera ..	" Simuliidae ..	5.8

(b) THIBA RIVER, ALTITUDE 8,200 FT. (Forest)

		Per cent
Ephemeroptera ..	Fam. Ecdyonuridae ..	76.4
" ..	" Baetidae ..	11.8
Diptera ..	" Simuliidae ..	11.8

(c) THIBA RIVER, ALTITUDE 7,000 FT. (Bracken)

		Per cent
Ephemeroptera ..	Fam. Baetidae ..	60.7
" ..	" Ecdyonuridae ..	11.4
" ..	" Leptophlebiidae ..	7.1
Plecoptera ..	" Perlidae ..	7.1
Trichoptera ..	" Hydropsychidae ..	3.5
" ..	" Leptoceridae ..	3.5
Diptera ..	" Chironomidae ..	3.5

(d) THIBA RIVER, ALTITUDE 5,800 FT. (Native Reserve)

		Per cent
Ephemeroptera ..	Fam. Ecdyonuridae ..	43.0
" ..	" Baetidae ..	13.5
" ..	" Oligoneuridae ..	2.2
Plecoptera ..	" Perlidae ..	2.2
Diptera ..	" Simuliidae ..	37.0
Trichoptera ..	" Hydropsychidae ..	2.2

There is one difference between the rainbow and brown trout. The rainbow, as soon as he is large enough, becomes a crab eater, and continues so until death. Brown trout are far less partial to crabs, and brown trout streams, however overstocked, will yield crabs. Many anglers will not admit this because the crabs are not in evidence during daylight. One well-known angler was convinced by putting down baited wire traps in places he vowed were devoid of crabs. Next morning the traps were full and individuals of all sizes were vainly trying to get in. The same experiment conducted in a rainbow river would have yielded a blank or just one or two large individuals.

A $1\frac{3}{4}$ lb. rainbow can contain as many as twelve crabs, running from $\frac{3}{8}$ in. to $2\frac{3}{8}$ in. across the widest part of the carapace. The other remarkable thing is the short time the gastric juices of the trout's

stomach need to dissolve the hard covering of the crab. The pincers are passed through the intestines whole, but the carapace and most of the legs are dissolved within twenty-four hours of the crab being swallowed.

The typical stomach contents of a big rainbow will differ from those of a large brown in that the latter will contain far more underwater and terrestrial insects. This may lead the angler to believe that the brown trout is more of a free-rising fish than the rainbow; but it must be remembered that the insects upon which the brown trout feeds are nocturnal in habit. The rainbow is a faster growing fish, therefore it must have more and a larger individual food.

HYBRIDS

This subject has been thoroughly discussed in Part I.

STOCKING

To show the rate at which a river can be populated by introducing fish, the case of the Thiba River may be quoted. In 1933 seven rainbow trout were planted in this river, and, as far as is known, no other fish were introduced before or after that date. In 1938 the total number of trout caught there and retained by anglers was 1,600, and in 1939 it will be about 3,000. The river, in its upper reaches, has been opened to unrestricted fishing, to try to reduce the stocks to what the food contents of the river can carry.

RAINBOW *versus* BROWN TROUT

When rainbows have been introduced to a brown trout river, sooner or later the rainbows have gained the upper hand and ousted the browns. The main reasons for this seem to be as follows:—

(a) The far greater adaptability of the rainbows to warm water.

(b) As they grow quicker they must have more food, and therefore are far more active in getting it.

(c) They are much freer spawners. Also they spawn many more times in their short lifetime than the browns.

(d) They instinctively migrate whenever the opportunity offers and therefore cover all stretches of a river.

(e) Their ova are far more hardy and the young are more vigorous; they retain this character throughout their life, shorter though it is.

CONCLUSION

The Future and a Policy

Enough has been said, I hope, to give some idea of the brown and rainbow trout and their environment in Kenya Colony.

The past is gone and finished with, and we have to consider the present and to think of the future. The Game Department in charge of trout fishing must think and plan at least five years ahead of the angler, or he will get no fishing.

Firstly, however, a few words on the relation the Government of this Colony, through its Game Warden, bears towards the trout rivers. The Government insists upon every person, of whatever creed or colour, being in possession of a trout licence before a trout may be caught. In return for this the Government endeavours to provide good trout fishing, both as a recreation for the inhabitants of the Colony and as an added attraction for tourists. The revenue derived from licences will depend on the quality and quantity of the trout fishing available. The following table shows the yearly revenue derived by Government since it took over trout fishing:—

YEARLY NUMBER AND REVENUE FROM
TROUT LICENCES

	1927	1928	1929	1930
Total Number of Licences Sold ..	228	250	725	916
Revenue Collected ..	£374	£370	£570	£632
	1931	1932	1933	1934
Total Number of Licences Sold ..	1,409	1,508	1,625	1,507
Revenue Collected ..	£910	£1,018	£985	£973
	1935	1936	1937	1938
Total Number of Licences Sold ..	1,447	1,636	1,439	2,039
Revenue Collected ..	£893	£968	£1,004	£1,117

These figures show that the revenue is increasing, especially in the last two years. In 1939 the figures are again on the upward grade, so it appears that Government is providing good trout fishing.

It is also interesting to discuss what the public expects from Government in return for purchasing a trout licence:—

- (a) Plenty of fish of a good average size and with a good sprinkling of really big fish.
- (b) The trout to be free-rising and easily caught by any legal means.
- (c) Motorable roads to places on the rivers.
- (d) Camps and camping places.
- (e) Easy banks and no obstructions.
- (f) Attentive and obedient service from subordinate official servants.
- (g) Cheap licences.

The policy for the present and the future should therefore be to meet these requirements, in order to cater for the public and bring in an increasing revenue.

It is perhaps permissible to point out that an increasing revenue should imply an increasing expenditure on the rivers.

From a consideration of the various factors reviewed above, it is clear that the fish that most nearly fulfils all our requirements is the rainbow. There is, however, a small proportion of the angling community in Kenya that strongly champions the brown trout, and with this minority one must have considerable sympathy. Their argument is that we should provide sport of the best kind we can, and let considerations of revenue go hang. However, they are a minority and a small one, and Government naturally considers as generally paramount the claims of the great majority of anglers—less skilled and less exacting. Future policy may therefore lie along the following lines:—

- (a) Retain and maintain the few brown trout rivers for the people who want brown trout.
- (b) Provide roads of access to all the rivers and paths of access up and down them.
- (c) Provide camps and camping places with as many amenities as possible.
- (d) Move brown trout down-stream from the upper overstocked waters by artificial means.
- (e) Provide easy migration facilities on all rivers, especially those with rainbow trout.
- (f) Increase the food contents of the rivers by improvement works.
- (g) Keep down the head of fish, especially in rainbow waters, in order to obtain a balance between food and stock.

Of these, perhaps the most important and least recognized necessity is the last.

RAT CONTROL MEASURES

The following is a reprint of Bulletin No. 31 of the Forest Department, Kenya

GENERAL REMARKS

Rats damage plantation trees by ring-barking them from ground level upwards. In the case of pruned trees, the lower six to nine inches of the stem are normally attacked. Small unpruned stems may be peeled almost completely up to a height of five or six feet. Species most commonly damaged are Cypress and Cedar, and to a lesser extent Grevillea. Other trees have also been attacked. The size of the trees affected varies from small unpruned Cedar four feet in height up to Cyprresses with a basal diameter of ten inches.

Probably the short-tailed vole does most of the damage, though an animal resembling the house rat might be responsible for some of it. The striped mouse is very common in plantations, but tooth marks on barked trees appear to be too large to have been made by so small a creature.

In certain districts an infestation of bark-eating rats may be expected during and after an exceptionally wet season, which favours heavy weed growth. Attacked trees may take many months to turn colour or die, while others make remarkable recoveries. As the rats almost invariably work under cover, it follows that very severe damage may be done before the effects become visible. It also follows that ring-barked trees should not be cut out until they actually die.

CONTROL MEASURES

There are three main methods of restricting losses:—

(a) *Patrolling*

When it seems that an infestation is likely to occur, reliable patrols should be sent round to inspect all vulnerable areas

at least once a week. Attacks, when they occur, are frequently very sudden and sporadic. An infested area may be surrounded by plantations of the same species and of the same age which are untouched.

Since debarking takes place under cover, inspections must be thorough; it is of little use walking round the outside of a suspected area. Where damage is occurring, however, it is fairly obvious to anyone walking through the plantation.

In vulnerable areas patrolling is extremely important.

(b) *Cleaning*

Once rats have attacked an area in any numbers, the only safe remedy is to clean all weeds and rubbish away from the bases of trees of the species being attacked. It is probable that the fear of being caught out in the open is what stops the rats from debarking trees in cleaned areas. Thus cleaning should be carried out right up the row rather than in circles round the bases of trees only, as cleaning the row allows more scope to the natural enemies of the rats.

Each strip should be about four feet wide, and so long as the ground remains clean this affords complete protection.

Where rats are working it is advisable to put a big gang on, and to get the area cleaned as soon as possible, even if this means abandoning all other work for the time.

(c) *Poisoning*

Cleaning discourages the rats from attacking trees, but as soon as the undergrowth grows up, reinfestation is likely to occur. Poisoning is therefore carried out in conjunction with cleaning operations. Baits are laid in the area into which it is probable that rats will be driven during

cleaning, i.e. work is started at one end of a plantation and poison is laid in that part of the area which will be cleaned one to two days after the baits have been put down.

Where plantations are surrounded by other vulnerable plantations into which rats may be driven, baits should of course be laid in these other areas as well. It is not necessary to poison cleaned areas. The poison used is barium carbonate mixed with stiff maize-meal porridge (posho). The bait should be laid in pellets of fair size as, in dense weeds, small ones are apt to be overlooked. A mixture of $\frac{1}{2}$ oz. barium carbonate to $1\frac{1}{2}$ lb. posho should make about 100 to 110 pellets. Fresh poison should be mixed daily. Normally one bait may be laid at the foot of every third or fourth tree in every alternate line. Where grass or weed growth is particularly heavy in an infested area, there is usually a correspondingly severe infestation of rats. In such small areas a bait may be placed at the foot of almost every tree.

Few dead rats are found, but the baits are usually taken, and as a treated area stinks on a hot day it is probable that the animals die in shallow holes, etc.

As the actual work of laying poison does not take long, it is convenient to use

the bait layers as patrols. They treat an area ahead of the cleaning gang and then inspect other plantations. Wherever they see that a few odd trees are being attacked in a new area, they lay poison. If this does not check the infestation within a day or two they report the fact, and the area is then cleaned. When the infestation is severe from the first, baiting by itself is not usually effective.

Trapping is of doubtful value if poisoning is well done. The ordinary wooden snap traps soon warp, and the traps are then generally useless.

COSTS AND TASKS

In one district the labour costs of cleaning worked out at Sh. 480/10 for 493.2 acres, equivalent to 97 cents per acre. The work was thoroughly supervised. Wages of poisoners were Sh. 77/90, and cost of posho Sh. 24/72, bringing the total costs to Sh. 1/20 per acre.

Latterly piecework has been applied in the case of cleaning. A fair task per day in normal weed growth appears to be a line of about 150 trees at 6 ft. x 6 ft. or 115 trees at 8 ft. x 8 ft., per man. Heavy weed growth must be cut down in the adjacent nurse-tree line by the same man, but cleaning of the ground is not necessary in the nurse line.

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ROADS AND THEIR RELATIONSHIP TO SOIL CONSERVATION

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INTRODUCTION

The importance of good roads as an aid to government and an encouragement of prosperity was appreciated by the Romans in Britain. Their straight, hard-surfaced ways remain as their enduring monuments to this day. Rough roads, dusty in dry weather and muddy in wet, which hinder intercourse and the spread of new ideas, make administration more difficult and expensive as well as less efficient. The increase of prosperity in the community is retarded by bad roads, in that the cost of transport of exportable surpluses of agricultural and pastoral products is raised and movement of goods is made slower and more difficult, so that increased production is retarded.

In Kenya our roads, the blood vessels along which flows the trade of the Colony, vary from tarred or macadamized highways, the arteries feeding the railways, down to the native footpath or dusty cattle tracks—merest capillaries of the system of communications. Even the smallest of these tracks has some effect on the land by altering the ecological environment. The roadmaker is both a sufferer from the effects of soil erosion and a causer of soil destruction.

In the first place, the road-builder has to guard against erosion of the road surface by rain which falls upon it, and to dispose of this water as rapidly as possible. Secondly, he has to protect his road from run-off water derived from the land on either side of the road. This is especially a danger if the land is cultivated, or heavily overgrazed, right up to the edge of the road.

This practice—common in Kenya, particularly in native reserves but also frequent in European areas—is responsible for excessive wash and the silting up of ditches and culverts. In turn, the latter occurrences result in flooding and damage to the road as well as inundation and erosion of the cultivated fields lying below the road.

On his part, the road-builder or the man who starts a new track may be responsible for increased erosion in the countryside through improper alignment of the road or through inadequate or ill-planned drainage. On the more expensive types of road, erosion may be due to failure to protect cuts and fills. It is very usual also for old roads to be abandoned, in native reserves and on farms, without any attempt being made to block these roads and so to prevent them from eroding into deep gullies.

It is commonly objected that more efficient erosion control on the road systems is bound up with the necessity for a far greater expenditure on their construction and upkeep, especially in the matter of the provision of a large number of culverts. This is only partially true. Attention to certain principles would avoid a great deal of needless erosion; nor can it be accepted that the intentions of the road engineer and the soil conservation engineer are inevitably diametrically opposed, the road expert wishing to drain water away by the quickest course, while from the soil conservation point of view it is desirable to drain the water away more slowly. Roads that are technically correct from the soil conservation aspect are also more attractive highways and require less



Photo by kind permission of Mrs. R. Ward.

A neglected road drain. Erosion caused by discharge from a culvert down a hillside on the Kinangop, Kenya Colony.

attention to maintenance, though in some cases the initial expense of construction possibly may be rather more heavy.

It is the purpose of this article to suggest ways and means by which the road engineer, the administrator, the farmer, or the native may co-operate to obtain both good roads and land unspoilt by uncontrolled run-off.

ROAD ALIGNMENT

It is evident that roads made on steep grades will be more liable to erosion, both of road and drains, so more care in aligning the roads, or realigning them when necessary, will assist in reducing the amount of destruction of road surface and drain bottoms by the run-off water.

ROAD CONSTRUCTION AND DRAINAGE

The most important principle in road-making is to obtain good drainage of the

surface of the road and also to prevent water from reaching the road from either side.

Earth roads in Kenya rarely have the banks at the side sloped back, but commonly the banks are raw vertical edges which continue to crumble and erode back into the field. Drains usually are cut with vertical sides, and the flow of water along the narrow bottoms often deepens the drains into dangerous gullies in ten years or so.

Where possible, instead of making ditches parallel to the road, with short mitre drains leading from the road to the main ditches, the sides of the road should be sloped back while the drains, made at the sides of the road and continuous with them, should be broad, with a gently curving section. Both roadside slopes and the edge of the road, including the drain, should be planted with grass.



Photo by kind permission of Mrs. R. Ward.

An abandoned road in Naivasha Township, Kenya Colony. This road eroded so badly that the drains met. A new road had to be built.



Photo by kind permission of Mrs. R. Ward.

An eroded drain on the Naivasha Escarpment.

This type of road and table drain necessitates the use of a wide cross-section. Roads of this nature have been made recently by the Public Works Department of Kenya across the Kano Plains near Kisumu. Roads with a section of 50 feet were also made, without side drains, along part of the main Eldoret-Burnt Forest road and the Sergoit-Farm 35 road. These wide roads were made for reasons of drainage and economy. There are no side drains and mitre drains to be kept clean by hand labour. Most of the maintenance can be done by machinery, and maintenance is greatly reduced by allowing grass to grow on the shoulders and in the table drains. However, the Divisional Engineer, P.W.D., Kisumu, comments: "This wide section will never be popular on farms owing to the cost of construction and the amount of land required."

In the U.S.A. the recommendations of the Bureau of Public Roads are as follows:—

"The minimum graded width of road-bed from out to out shoulders shall be not less than 26 feet in easy topography, not less than 24 feet in rolling topography, and not less than 20 feet in mountainous topography with a greater width than the 20 feet minimum on through fills. Where roadbed slopes are flattened to a 3 or 4 to 1, the minimum graded width in easy topography may be reduced to 24 feet."

With regard to the slopes to which the edges of the road should be cut, it must be remembered that, while compact earth has an angle of repose of 29° to 50° , wet clay has an angle of repose of only 16° , or $27\frac{1}{2}$ per cent. Flatter slopes than these will be necessary, however, if a good protective cover of vegetation is to be encouraged.

Although grassed roads will not stand heavy traffic, roads subjected only to light

or moderate traffic keep a far better surface if the grass is cut rather than periodically removed completely. The custom of maintaining a completely bare road rather than a road covered with short grass is particularly common in certain native reserves. Exposed and dusty roads are far more apt to wash into bad holes and ruts than they would have been if the grass had been cut short rather than cleared off completely. As far as possible users of grass-covered roads should avoid driving in the same tracks so as to wear away the grass, causing the concentration of water along the tracks and the consequent formation of ruts in the road.

Farm roads and pioneer roads on hillsides, where catchwater drains with culverts cannot be afforded, certainly should be left with a cover of short grass. In such cases the road may be sloped gently in the direction of the slope of the ground. Drainage takes place across the road and not under it. The grass on the road protects its surface from erosion.

However, roads on hillsides which are subject to considerable wear require catchwater drains on the slope above the road, unless the cover is exceptionally good or the run-off from the hillside is negligible.

These catchwater drains discharge under the road at intervals by means of culverts. If the culverts are too few, or if the points of discharge are not selected with sufficient care, erosion will be caused by this discharge. As a rule, slopes which are adequately covered with grass can take a fairly heavy flow of water without suffering from erosion. If the cover is poor it may be advisable to plant roots of grass or sod strips beneath the culvert, reinforced with temporary brush dams to give the grass a chance of taking hold.

Where large flows of water are likely it may be necessary to place masonry and concrete aprons beneath the mouth of the culvert.

The water from the lower side of hill-side roads is usually discharged by a series of short drains taking the water from the edge of the road and leading it down the slope. These short drains should be frequent and their grade should not be too steep. The drain at the edge of the road may be dammed to direct water into the side drain. If considered necessary, short ditches can be made on the contour two or three yards below the end of the side drain in order to spread the water over the slope.

Shallow drains at the side of the road, such as have been described in the previous paragraph, should be planted to Kikuyu grass or Star grass. Drains that are well covered with one of these grasses should be able to take a flow of 8 or 10 cusecs on a slope as steep as 12 or 15 per cent. If the grade of the ditch is steeper than 12 or 15 per cent it will be necessary to place a few low check dams of stone across the drain in order to reduce the grade in between the checks to a more desirable slope, and so to reduce the velocity of the water and its cutting power. The only maintenance of the drains that is likely to be necessary is cutting the grass occasionally.

A great deal of interest has been taken in Texas and neighbouring states in the improvement of road design and road drainage in order to facilitate conservation of the soil. The Engineering Handbook of the Soil Conservation Service, Region Four (Arkansas, Louisiana, Texas and Oklahoma, exclusive of the Texas and Oklahoma Panhandle sections), makes the following observation on highway drainage:—

"The road channel should be of such depth that a minimum free-board of 6 inches is maintained at all times between the maximum designed flow in the channel and the shoulder of the road. The minimum channel depth should in no case be less than 2 feet for dirt or gravel roads or less than 1½ feet on hard surface roads. The bottom width should be the designed bottom width necessary to take care of the drainage area. Bermuda grass [*Cynodon* sp. or Star grass.—C.M.] is recommended wherever available, and in cases where outside drainage area must be taken care of immediately after construction, the channel should be solid sodded over an area necessary to take care of the maximum designed flow, and the remaining area broadcast sodded. In cases where no outside drainage empties into the road ditch, it should be possible to use broadcast sodding over the entire area. Strip sodding should not be used for roadside erosion control except in cases where the scarcity of sod makes it impossible to use solid or broadcast sodding. Due to the numerous failures of spot sodding it is not recommended for use in any areas. A liberal application of fertilizer should be made with all broadcast and strip sodding, and where the sodding is done during the dormant season a nurse crop should be sown."

ROAD RESERVES

For practical reasons connected with the maintenance of the road and the protection of agricultural land from erosion, it is necessary that the roadmaker should have some control over the land immediately contiguous to the road. Especially in countries such as Kenya, where tourist traffic may become increasingly important, the preservation of trees, bushes and grass along the verge of the road must also be considered from the artistic point of view.

The standard width for main roads is 120 feet; that is, 60 feet measured from the centre of the road if no surveyed road reserve exists. Probably a narrower reserve would be adequate for district roads.

The amount of water discharged into road drains from the road above naturally is dependent on the land use on the slopes. Here is yet another argument for proper land use, utilizing the steeper slopes for grassland or forest, or at least employing such agricultural methods of terracing, strip-cropping and manuring as will decrease run-off, by increasing permeability of the soil, and will dispose of surplus water in an orderly manner.

Especially in native reserves, over-grazing or cultivation on the land immediately contiguous to the road results in run-off water from the land, which is often eroded, flowing across the road and carving numberless little furrows, which add nothing to the comfort of the traveller by motor car or lorry, and which cost a great deal of labour and money in road repairs. This tendency to cultivate the land right up to the road ditch is particularly prevalent in the more thickly populated native reserves, in which the preservation of a wide road reserve would be regarded as waste of good land.

It is most important that the question of standardization of road reserves in various parts of the Colony should be examined by responsible authorities and the widths laid down for various classes of roads. It should be insisted that a substantial strip on either side of the road should not be grazed or cultivated, but should be left under some form of vegetation which would absorb and spread run-off water from the land above.

Under the Native Lands Trust Ordinance, 1938, a sufficiently wide strip of land could be "set apart" for this purpose. By arrangement between the Public Works Department and the local authority it should be possible to plant this strip with trees (except in very moist

areas where the shade of the trees might keep the road too damp). These trees would provide timber and fuel, while they would shade the weary traveller and act as windbreaks for crop land and pasture.

Alternatively, this strip of land alongside the road could be planted to a fodder crop like Elephant grass, or a hay crop, which perhaps might be cut, cured and stored by communal effort.

FARM AND FIELD ROADS

The correct location and construction of farm and field roads is very important in controlling erosion on the farm.

Farm roads must be placed so as to prevent, as far as possible, the concentration of water, even if this involves making the length of the roads rather greater. The roads should be situated where they will serve best those buildings and fields to and from which heavy loads will be hauled.

Inadequate drainage is the main cause of poor farm roads. Seepage water from the hillside or roof water from farm buildings may make wet spots in the road throughout the wet season. The road surface may be destroyed by erosion if the grade is too steep.

The type of soil, necessary drainage, and road material available on or near the farm should be considered before starting to make the road.

Quoting the Engineering Handbook of Region Four of the Soil Conservation Service, U.S.A., *in extenso*:—

"The surface width should be a minimum of 8 feet with an additional 2 feet on each side between the traveled way and the ditches. The center should be higher than the sides to permit rainwater to run off. A crown of $\frac{1}{4}$ inch to 1 inch per foot is recommended. The side

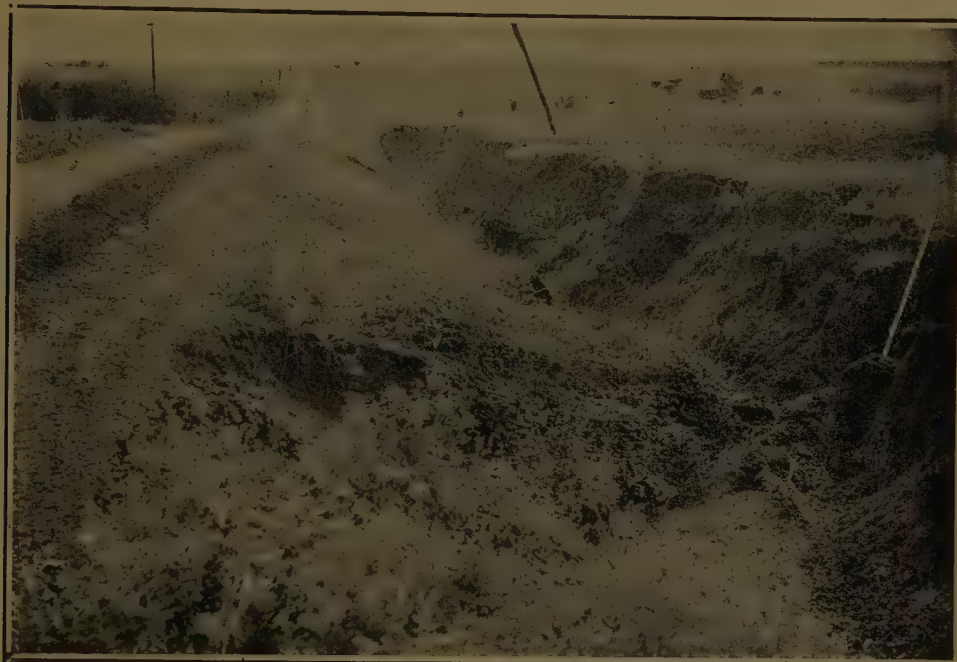
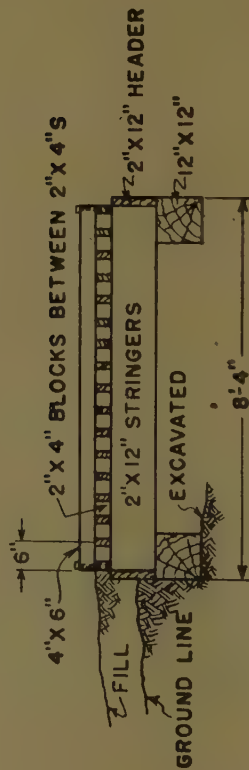
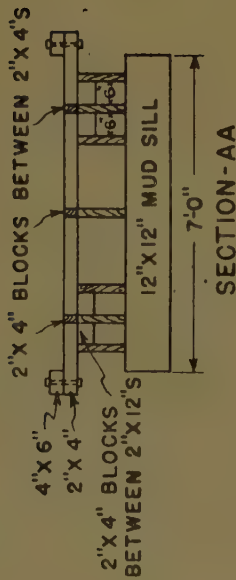
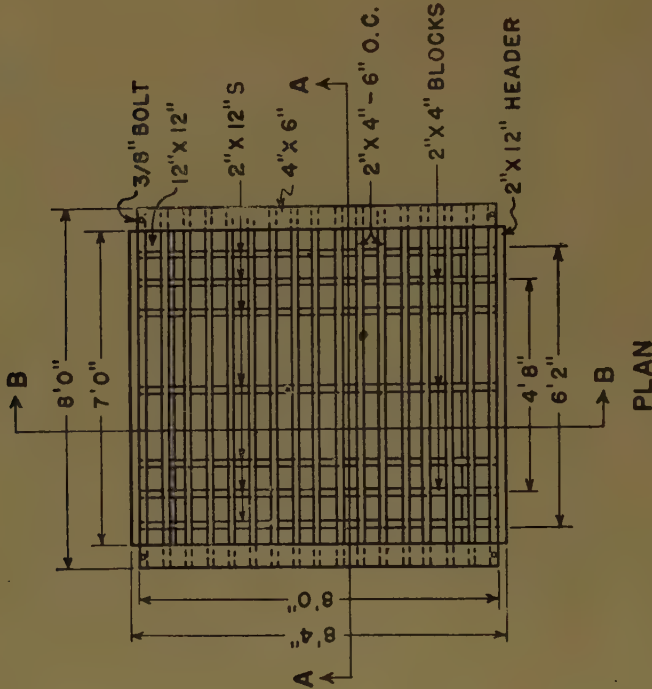


Photo by kind permission of the Soil Conservation Service, U.S.A.
An eroding road bank in Texas with lateral gullies eating back into adjoining land, and an eroding road ditch. This picture shows a road edge which is typical of many in Kenya.



Photo by kind permission of the Soil Conservation Service, U.S.A.
The same road bank and ditch following work done as a co-operative project by the local road authority and the Regional Soil Conservation Service. The bank and ditch have been sloped and sodded. Capital assets are being preserved, the road made more safe for traffic, and the appearance improved.



Note.—All timbers in contact with earth should be creosoted.

Scale: 1/4 in. = 1 ft.

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ditches should be designed to take care of the run-off; and where erosion control measures are necessary, they should be installed as in terrace outlet channels. To facilitate quick removal of water, culverts and ditches should be carefully designed.

"The road should be surfaced wherever possible with some native material such as crushed stone or gravel to prevent ruts which will collect water and cause gulying. However, as surfacing farm roads will be impractical in most cases, it is recommended that as much vegetation as possible be allowed to remain on the road surface and that the formation of tracks be avoided as much as possible by not using the road any more than is necessary during wet weather. The hazard of concentration of water in ruts and tracks can be largely overcome by locating the road as nearly as possible on the contour.

"Individual field roads may not require the same treatment as other roads on the farm because they are not used as often and are seldom used during wet weather; however, they must be so located that they provide access to all parts of the field. In terraced fields the most desirable road location is immediately below the terrace ridge. This puts the road as nearly as possible on the contour and, also, it will receive less water at this location than at any other place in the field. Where the road cannot be located on the contour, it may be possible to locate the road in such a place that the road ditch can be utilized for a terrace outlet channel. Should the road ditch be used as a terrace outlet channel, it should be designed, constructed and sodded according to terrace outlet specifications. The danger of this location, however, is the destroying of the sod in the ditch in crossing from the road to the field between each terrace. A more desirable location is one where the water can be drained away from the road. If this method is used, the terraces may be blocked across the road ditch to intercept the run-off at each terrace. This will usually provide sufficient control and no sodding will be required in the road ditch. However, there is always danger of gulying in tracks where either of the above methods are used. Another and more desirable method of intercepting the road water is to construct the terraces across the road. This will require a terrace section across the road of such height and width that it can be easily crossed with farm machinery. This type of construction allows each terrace to intercept its portion of

the run-off and prevent run-off from flowing the entire length of the slope down tracks in the road. This type of road has proven satisfactory for roads along the closed ends of terraces and for roads through the center of fields, where terrace drainage divides. Roads should never cross terraces at points where water must pass and neither should they cross areas where water is emptied."

CUTS AND FILLS

The exposed earth on cuts and fills is likely to wash badly and to slip so as to spoil or destroy the road unless special measures are taken.

In the first place, the slopes of both cut and fill should be no steeper than 1:1 (45°). The soil on the freshly exposed surface or on the newly constructed bank can be stabilized temporarily by pegging it down with a number of little wattle hurdles, the stakes of which are driven two or three feet into the earth, aligned on the contour.

Seed of small annual grain crops, like wheat, rye, or finger millet, can be scattered on the slope to afford temporary protection. Permanent protection can then be arranged for by planting cuttings of suitable local bushes or roots of Star grass or Kikuyu grass.

In California many steep cuttings in rather dry areas have been given good protection by planting with succulents or a drought-resistant *Mesembryanthemum* species.

The use of vegetative means of control, coupled with the practice of sloping back the sides to the required grade, often enables banks and cuttings to be consolidated and rendered secure which otherwise would require heavy expenditure on stone revetment.

In some cases it may be found desirable to expedite the growth of the vegetation by applying a dressing of *boma* manure or of artificial fertilizers.

ABANDONED ROADS

Abandoned roads should not be left to develop into gullies. They should be blocked across at intervals by check dams of wood, earth, brushwood, or stone. These small check dams will hold up silt and moisture and enable grass and other vegetation to take a hold so that erosion is prevented.

CATTLE TRACKS TO WATER

The continual passage of cattle up and down to water, especially when the stream or dam at which they drink is at the bottom of a steep slope, is a prolific cause of bad gullies in Kenya Colony.

The palliative often is suggested to be to fence off the track and to make the cattle use another. In fact, this practice only results in a series of gullies being formed. It is not possible as a rule for the original gully to reclothe itself rapidly with vegetation, and the vegetation which grows on the eroded track is soon trampled away when the track is brought into use once more.

The best course is to arrange for *one* track to water to be used, and this track should follow as gentle a gradient as is practicable; it should not plunge headlong down the hill. Across the track itself should be made a series of broad-base terraces at the standard spacing. The cattle should be obliged to walk up and down these ridges by means of thick, confining hedges of thorns, Euphorbia, or other suitable plants. The channels of the terrace ridges across the road should

discharge into a wide grassed channel running downhill on one side of the road and on the far side of the hedge. Star grasses or Kikuyu grass are the best grasses to protect the channel.

Cattle generally tend to follow a narrow footpath, one behind the other. Owing to this habit, the banks may be worn down here and there and will need repair periodically. Alternatively, the points at which the cattle customarily crossed the banks can be protected with slabs of stone.

CATTLE GUARDS AND BRIDGES

The European cattle-owner may wish to place cattle guards or bridges across ditches or small gullies which intersect his roads. A plan of a cattle guard used in Texas and approved by the Regional Engineer of the Soil Conservation Service is published in this article.

ACKNOWLEDGMENTS

I wish to acknowledge the assistance given to me by Mr. J. E. M. Noad, Divisional Engineer, Public Works Department, Kisumu, who read through the first draft of this article and made several valuable criticisms and suggestions. I acknowledge also my indebtedness to Mr. Howard Matson, Regional Engineer, Soil Conservation Service, Fort Worth, Texas. I was able to inspect some of Mr. Matson's work on roads in Texas and to discuss the question with him. I have drawn freely upon the valuable Engineering Handbook of Region Four, which was kindly sent to me by Mr. Matson.

PERENNIAL GRASSES AND SOIL STRUCTURE

The following account of the action of the roots of perennial grasses upon soil structure is extracted from the Journal of the American Society of Agronomy for 1937, pp. 89-90. The author is Dr. Richard Bradfield, a leading physical chemist, who explains earlier in the same paper that he himself remembers, as a boy, ploughing virgin prairie sod on a farm that is now on the fringe of the "Dust Bowl". The soil condition he then noted, and now describes, is one which practical farmers are striving to reproduce in their over-cultivated or overgrazed lands with the aid of suitable grasses.—ED.

Grass roots are so numerous that in a well-established sod they are seldom over 3 to 5 millimetres apart. Each root represents a centre of water removal. As water is removed the small fragment of soil between the roots shrinks and is blocked off by the roots. The pressure developed by the capillary forces, compressing the granule from all sides, is great; in many soils it reaches over 5,000 lb. per square inch. As a result these granules become quite dense, their apparent specific gravity ranging from 1.8 to 2.0. The total pore space inside them is small and the size of the pores is very small. Water moves into them slowly, but is held firmly. The pores are so narrow that they are easily completely sealed by capillary water and as a result the ventilation of the interior is poor. Consequently, reducing conditions frequently exist in the interior of the granules simultaneously with oxidizing conditions on their surface. This often causes a migration of substances which are more soluble when in the reduced form to the surface of the granules, where they are oxidized and deposited. This deposit serves as a cement and helps to stabilize the granule.

In forcing its way through the soil many cells are sloughed off the living root

and serve as food for bacteria. Eventually the roots die and are decomposed in situ, forming a humified, often water-resistant, coating around the granule. The marked difference in colour between the surface of such granules and their interior is evidence of this. In the strongly granulated soil practically the entire mass of clay and silt particles are clumped together in these water-stable aggregates. As a result there are two fairly sharply defined groups of pores in such soils, capillary pores within the granule and non-capillary pores between the granules. The non-capillary pores are relatively large. Such a soil has a permeability approaching that of sandy soils combined with a storage capacity of the heavier-textured soils.

Such are the structures which perennial grasses tend to develop in soils. Such soils provide optimum growing conditions for most crops.

It is not known how many seasons' growth are required to produce the optimum structure. The major part of the work is probably done in the first few years of growth of the sod.

The development of the desirable structure involves the use of growing plants.

SOME ASPECTS OF MODERN PRACTICE IN SOIL SURVEY*

By G. Milne, M.Sc., F.I.C., Soil Chemist, East African Agricultural Research Station, Amani

The present-day outlook upon soil survey has been aptly summarized in the statement that its results form "the factual basis in the development of sound programmes of land use." The growing literature of the subject now constantly reminds those who are applying soil science in this branch that it is *the land* that is the reality that is to be investigated, classified, inventoried, and interpreted. Soil maps and survey reports are to find their justification as guides to the efficient use of the land; they are necessary documents in the framing of policy, whether local or national, in regard to rural production.

The soil surveyor, then, regards himself as a contributor to the study of land questions who distinguishes his land types primarily by soil characteristics. His first duty in this capacity is the expert recognition of the varieties of soil that exist in his piece of country and their reduction to a manageable number of named types. In this stage of his work he is a pure scientist, adding to soil knowledge or establishing the applicability of existing knowledge in a new area. He classifies and describes his material to his own satisfaction, in whatever terms the technicalities of the subject require.

As he goes about in the field making his map, plotting the occurrences of his soil types, he must, however, bear in mind his duty of making clear, to all who follow him on land questions, what his data signify. The pattern he provides must, as far as possible, speak for itself to the others who will be dealing with the same area

(such as agricultural advisers, foresters, administrators, or those who organize communications), without further visiting of the ground being necessary for the ascertainment of relevant facts regarding land type. Qualities such as topographic character and slope (expressively summarized in the American language as "lay of the land"), stoniness, other kinds of irregularity of surface (such as, in Africa, termite mounds), depth available for root development, nature of plant cover or of customary crops, susceptibility to accelerated erosion, degree of erosion already suffered, exposure to wind or liability to river overflow—all these are relevant and must be incorporated along with soil profile and texture of top soil into the definition of soil types. The soil types thus virtually become "natural land types," and it is these that are to form the pattern of the map, the units which form the items in the completed inventory.

The natural land types having thus been determined on the basis of their physical and, to some extent, their biological characteristics—the latter from the ecological viewpoint of describing each land type as a distinctive "habitat"—their description can be carried further in the report by recording briefly whatever can be ascertained of man's experience in occupying them. There is a wide field of relevant inquiry here: crop-plant behaviour, crop yields and qualities; thriftiness of stock, stock-carrying capacity, rates of natural increase; human population densities, human health, attainable standards of life earned on the land. "For example, one

* This article contains the substance of a further chapter of Mr. Milne's Report on his visit in 1938 to parts of the West Indies and the United States. A previous article, on soil and vegetation, appeared in our March number.—Ed.

cannot make a suitable map of land on the basis of tax delinquencies; but data regarding tax delinquencies, when classified according to soil types, may be suggestive regarding the capabilities of these for use."¹

If the natural land types are defined in this way and their description amplified with accessory information, much more is conveyed to the user of the results of the survey than if soil types only, in a narrower technical sense, were employed. A soil surveyor working to such objectives must, correspondingly, be more than merely a trained observer of soil profiles, though of course he must be that first. He needs to have a good eye for country. He should be able to understand topography in terms of physical geology. He should be a student of climate and its effects. He must know something of vegetation and plant succession. He should have enough acquaintance with crops and cultural practices to enable him to estimate what have been, and what will be, the probable interactions between man and the soil in both directions. In virgin or recently settled country the natural land types will stand out clearly, but in long-occupied territory they will not be easy to disentangle from the man-made pattern of social land units and customary usage; vegetation will then give little help, drainage conditions may have been altered, and the top soil itself is no longer the A-horizon of a natural profile—it is the M-horizon, or horizon of disturbance by man. In such a case the correct interpretation of soil conditions may depend as much on inquiry, even on historical research going far back, as on actual observation. The soil surveyor must have judgment in sifting the results of inquiry amongst the occupants of land, and must take history as well as geography into his field of interest.

The results of soil survey then, whilst being based on sound pedology, must be so reported as to convey a maximum of information regarding land types.

How best to translate these by no means simple requirements into field practice and mapping and report-writing technique has been a subject of considerable study of recent years amongst soil surveyors, particularly in the United States. There is, for example, a trend towards giving the factor of *soil texture* a greater weight when deciding upon the adoption of distinctive names for soils. This is because textural differences often carry profile differences with them—a good pedological reason; and because they are of importance in the soil-moisture balance-sheet and are often of deciding weight in tillage time-tables, cultivation costs, erosion defence measures and the like—a good reason bearing on land classification. Then there is the use of the notion of “slope phase” and “stoniness phase” within a given type, to denote differences in the ease of use of farm machinery or to mark the need for avoiding erosion-promoting forms of land utilization. In large-scale work for the special purposes of soil conservation, the mapping of degrees of erosion has been systematized, and devices are being evolved for informative generalization on this point in ordinary smaller scale surveys. On the still smaller scale needed for reconnaissance surveys, land types are necessarily less particularized, but here too they are being given more informative expression on maps; the representation of “soil complexes” is displacing the former practice of mapping only the “normal” or dominant soils, whereby the user of the map was left insufficiently advised of the occurrence of soil types departing from the normal for local reasons, e.g. the soils of poorly drained depressions. On the side of

¹ C. E. Kellogg, *Soil Survey Manual*, Washington, 1937.

agricultural economics there has been a development of methods for arriving at productivity ratings from soil and other data gathered during the course of the survey. These ratings are attempts to show the observable or predictable relations between soil and crop-yield in the condensed and tabulated form of a set of comparative numerical indices directly showing productivity; they are now included in most soil survey reports in the United States.

In adopting this principle of giving his field observations and worked-up results a practical turn, the soil surveyor has, incidentally, greatly clarified his own ideas of what are the essentials of soil description. To quote a writer speaking of the problem of soil-type description in the Tennessee Valley area:—

“We map Fullerton silt loam, a part of which occupies land of three per cent slope and a part occupies land of forty-five per cent slope. With the slope not mapped, data interpreted from such work would be inadequate information for the use-adaptation and management problems of Fullerton silt loam and would disqualify this soil type as a unit for land classification.”

The “steep phase” of a soil type is, in fact, *a different soil* from its normal or gently sloping phase, even though profile differences are slight. The practical usefulness of soil survey has benefited, and soil science itself has advanced, by the present-day recognition that “profile is not enough.”

As an example of the increase in effective value of a soil survey when both internal and external characteristics of a soil are recorded; i.e. when the older simpler concept of *soil type* is expanded into the newer one of *natural land type*, the following are listed by the Tennessee

Valley workers, as derived maps that can be plotted from the results of the soil survey as they are delivered in the regional office:—

A general productivity map.

A potential-land-use map.

A lay-of-the-land map, i.e. a map showing slopes and topographic situations.

A general erosion map, showing either the conditions resulting from erosion, or susceptibility to erosion.

A map of stoniness.

A detailed natural drainage map.

A crop-adaptation map.

A land management map.

A relative land-valuation map.

If the soils had been mapped on the older standard principles, only an imperfect productivity map and a drainage map could have been interpreted from the survey; to get the rest, the ground would have had to be gone over again by the specialists interested. It will be evident that by adopting the wider outlook, soil surveyors have greatly improved the economy of their work from the point of view of their employers and have made its results of immediate interest in a variety of directions.

In this on the whole very valuable return towards realism in soil survey, from the position of a few years ago when soil scientists were clarifying their ideas by the opposite process (necessary at that stage) of detaching themselves for the time being from the problems of practical land use, there is perhaps a risk of the pendulum swinging too far. Some of the printed reports that were given me as examples of recent United States practice in the working up of county soil surveys devote so much of their text to the cropping systems,

agricultural economics and general human geography of the area, that the proportion of pure soil description, and discussion and inference therefrom, seems rather meagre by comparison. In their very endeavour to produce a land-type classification with a practical appeal, soil surveyors may find themselves at times somewhat undervaluing the fundamental pedologic facts that are professionally their concern. The fact that a soil survey was called for is an admission that knowledge of soils in the area concerned was realized to be imperfect. Current agricultural practices and forms of land use are based on that imperfect knowledge and may need revision when it is improved. The soil surveyor is bound to take full note of them and will learn much in the process, but he should not necessarily allow his account of them to take priority over an independent account of his own findings. To the shoemaker, there should be nothing like leather!

The manner in which soil surveys in the United States are conducted, and the results carried through to publication, provides, or has provided until recently, considerable safeguards against the work falling below standard in aims or execution. Even for East African readers, who are unlikely for a long time to come to see soil survey going on around them on anything like the scale on which it is conducted in the United States, a short account of the organization that has been built up will be of interest.

Almost all soil survey projects are the joint affair of a State authority and a Federal authority, the details of the co-operation between them being settled on each occasion by a conference on the spot after the area has been reconnoitred. The participants in this conference are the members of the survey party, together

with one senior member each from the State institution and the Federal authority, which is ordinarily the Bureau of Plant Industry, Soil Survey Division, often nowadays with the Soil Conservation Service also co-operating.

The State soil survey staffs work under the auspices of the Agricultural Experiment Stations, which are usually associated with the universities or agricultural colleges. They bring a fund of knowledge of local conditions; they can speak their mind against over-standardization of methods where they see it to be inapplicable, and they can bring new ideas into the common pool, arising from soil characteristics or geographical effects that are manifested in their own region. (It must be remembered that the United States is a country of continental dimensions, from parts of which the capital at Washington is as remote as Nairobi is from Cairo or from Capetown.) Not of least value is that many men of the State staffs, particularly the senior men, are teachers, besides being active in soil survey. To have to teach a subject is a help in getting a balanced grasp of its essentials, and the combination of critical keenness and practical earthiness that is commonly met with in a class of final-year agricultural students is a good corrective to views that are losing touch with reality. The point especially to be made here is that not only soil science, but actually soil survey, is one of the subjects taught, at least in certain larger colleges. The existence of permanent soil survey staffs has naturally led to provision being made for feeding them with trained men.

The Federal authority in Washington sends field men to work alongside the State staff in the same party, and co-ordinates the result with the innumerable other soil surveys that have been, or are

being, carried out elsewhere. This co-ordinating service is rendered through a liaison staff of inspectors and through a headquarters technical staff who review all maps and reports and prepare them for publication, besides watching generally over the development of soil nomenclature, classification principles and survey techniques. The base maps on which the soil data are represented, on scales commonly one inch to the mile as published, but often larger than this for special purposes (e.g. on conservation projects), and always larger in the original field sheets, are sometimes available from topographical surveys, army maps, etc., but are often made by the field party itself as it goes along, by plane-tableing. Air photographs, taken to standard specifications, are now increasingly being used to reduce the labour of making base maps. The soil maps are finally printed in colour. The headquarters staff works in close contact with—in fact, in the same building as—a laboratory service busy in many research branches of soil science, and in the other direction has dealings with a number of the other services, bureaux and divisions through which the Department of Agriculture (including animal husbandry and forests) covers its vast field. Through these contacts it is unlikely that any tendency towards unbalance or partial vision in soil survey work could long escape correction. The Soil Survey Division is not over-generously financed by the standards of the country and is staffed to rather modest total numbers; it is small enough to be able to adhere to high standards in recruitment yet large enough to include a wide range of experience and outlook amongst its members. It impressed me as a very un-bureaucratic bureau—a happy family of keen workers. The portrait of Curtis F. Marbut, a pioneer of thought upon African soils, presides in the office

of the Chief of the Division, and the Provisional Soil Map of East Africa is amongst the representative soil maps of the world on permanent exhibition there.

A word may be said about the public to whom the printed soil maps and survey reports appeal when they are published. The county maps are in demand not only by agricultural advisory staffs, extension lecturers and the bigger occupiers of land, but also by public utility companies concerned with water and electricity supply, by highway authorities, irrigation boards, banks, land agents and farmers' co-operative organizations. They are used for purposes of local government, especially taxation in rural areas, and for educational purposes in schools. Editions of a thousand or so may run to exhaustion in a few years, and revision is called for. Soil maps have of course come into their own with the great increase in interest in land questions in recent years in connexion with agricultural adjustment, output restriction of certain crops, soil conservation, rural planning, revision of the bases of taxation, movement of population from eroded regions, reafforestation, irrigation development, and so on. The demand for soil surveys in California at the time of my visit was beginning to tax severely the capacity of the State authority (the University of California) to meet it.

This brings me to explanation of a remark made in parenthesis above, that the safeguards keeping soil surveys up to a high standard have operated "until recently". It is possible that the great expansion of soil survey programmes in the last few years (in the United States) has weakened these safeguards a little for some of the work carried out for urgent purposes, especially for soil conservation, under the new policies. It has naturally not been easy to staff all the multiplied

field parties at once with fully trained and selected men; a strain has been put on inspection and correlation procedure by the very mass of the accruing results; the "philosophy" of the new work has had to be evolved (as it has in all branches of the art of soil conservation) while the work itself was being pushed forward in quantity, and perhaps this has not always been accomplished *pari passu*. Some of the surveys for conservation purposes may be found in time to have lacked the basal quality that is desirable in all soil survey. The areas added as "surveyed" during this period of rapid progress may not be all permanent gain.

This is referred to, not as a criticism, but as representing a phase that we ourselves will be likely to pass through, in lesser degree, in the Colonial soil survey work that lies ahead of us. Little work of a detailed or systematic kind in this branch has been done in tropical dependencies, at any rate in Africa. The need for it will be felt in time—one would like to say that it *is* being felt, but at present that would be a minority statement—and we shall then be faced with difficulties of the nature of those just mentioned. Field men with the necessary qualifications to carry out good work of a "basal" kind will not be available until the demand for them has been in existence for some time; they will have to be educated, trained and given experience. The incentive to the initiation of soil surveys will not, most probably, be a conviction of their necessity on *general* grounds. It will be that particular problems arise, in which soil survey can help. Such special occasions may be in connexion with preventive and protective work on lands that are beginning to lose soil through erosion. A policy of increased food production in a native area may need guidance about soils. A plan for redistributing population or for

opening relief grazing grounds may call for soil data. A new crop may enter into a regional economy and needs to be fitted into the farming system to best advantage. A one-crop agriculture conducted non-intensively may realize its weakness in face of competition and decide to take stock with a view to concentrating more effectively on reduced acreages. A need for the rational use of fertilizers may be felt—and so on. There are occasions enough for soil survey in colonial dependencies, but each occasion, at any rate in the beginning, will be recognized on account of some particular urgency. And while the soil surveyors then set to work will have the duty of serving their employers first and of working to their terms of reference, an educated strong-mindedness against interpreting these too narrowly will be needed on their part if the results are to have the "basal" character that so much of the work in the United States now has; a permanence and a potentiality for usefulness in the future in unforeseen ways. It will be the more difficult to give the early surveys this character because they will be done without the support of a developed organization for inspection and correlation. Experience will be lacking alike at headquarters and in the field. There will be a risk of activity outrunning understanding. On unfamiliar ground (and how variable the setting can be in tropical Africa!) a field party working in isolation might well go through the motions of soil survey without having fully visualized their objectives.

For the reduction of some of these difficulties we shall probably do well to study carefully the reports and maps of two tropical surveys just completed under United States auspices. The soil survey of Puerto Rico was entering the publication stage, after five or six seasons of

field work, in 1938, and that of Hawaii was to be in its last field season in the winter of 1938-39. Cuba was the subject of a reconnaissance soil survey in 1927; the work was done for the assistance of a particular industry (sugar), but was not the less broadly conceived on that account. Two reconnaissance surveys bespoken by the sugar industry in the British West Indies (in Antigua and Trinidad) have recently been carried out by C. F. Charter, and are worth study as examples of method and procedure. The tropical survey that will be watched with most general interest is the detailed work now nearing completion in Trinidad under the direction of Hardy, of the Imperial College of Tropical Agriculture. The moving principle in this survey is a faith in the study of crop-ecology for the solution of production problems in tropical agriculture and forestry, and a belief that the foundation must be laid in knowledge of the soil factors. It is greatly to be hoped, from the point of view of colonial agriculturists, that the Trinidad survey will be afforded the means of publishing its maps and data in full, so that early advantage may be taken in other tropical regions of the experience that has been gained in it.

As regards the share that the chemist, as such, plays in the work of a soil survey, the view most generally found is that the pace of the work should be set by the man with the plane-table, auger, spade, pH-outfit, and good walking legs, rather than by the chemist with his more elaborate investigations, which keep him lagging behind. In country in which a fair amount is already known about the principal soils, the classification of land types, the drawing of the map and an outline description of the morphology and natural

history of the soils can usually be carried through without very heavy demands on the laboratory, except for checks on texture and certain routine determinations that can be done in quantity. In country where the principal soil types have not been previously investigated, a period of reconnaissance including thorough laboratory inquiry into soil characteristics is a very necessary stage in preparation for the survey proper. After that stage has been passed and the visual and tactile characters of the soils have become familiar and interpretable, the field party becomes to a great extent capable of independent progress; the necessary laboratory work can catch up afterwards. For the solution of particular problems in soil fertility or crop behaviour, the basis of the survey may of course need to be chemical to a much greater extent.

The American soil surveyors classify their types mainly by skilled observation in the field, and their classification works very well; it is reproducible in areas wide apart, and stands up to the test of subsequent chemical investigation. In Africa we shall be wise to go cautiously at first, and not let field classification run too far ahead of intimate knowledge. There are still too many of our principal soil types that are almost complete strangers to us on the laboratory side. Even so, soil survey conducted mainly in the field could already tackle some problems with practical effect, and the power of the method would grow with use. In these countries, still in an early stage of agricultural development, it might well be introduced in substitution for the method of trial and error. Here the soil surveyor could lead, instead of following after, when major readjustments of land use have become urgent, as in America.

REVIEWS

BIOLOGICAL CONTROL OF ARMILLARIA ROOT ROT.

Mr. R. Leach, lately Plant Pathologist to the Department of Agriculture, Nyasaland, has published his recent researches on the biological control of Armillaria Root Rot (*Trans. Brit. Mycol. Soc.* XXIII, Vol. 4, pp. 320-329, 1939, with 2 plates). His earlier observations were reviewed in an editorial note in this Journal in May, 1937, and have aroused general interest. His recent work confirms earlier conclusions to the effect that the ringbarking of forest trees some time prior to felling depletes their roots of carbohydrates to such an extent that they cannot be invaded by Armillaria and are killed by fungi innocuous to healthy plantation crops. These saprophytic fungi when established show an antagonism to Armillaria, which is unable to penetrate them. An example of practical interest is given in the case of thick woody prunings. When fresh prunings were buried in the soil along with roots of *Gliricidia sepium* infected by Armillaria, they were found to have become infected when examined one month later. A second set of prunings were left on top of the soil for a month to be invaded by various saprophytes, before being buried along with the fresh prunings. These dead prunings remained free from Armillaria and were hollowed out by termites, which are stated never to devour roots infected with this parasite. This answers a question occasionally asked by planters regarding the disposal of prunings.

Some difficulties which arise in applying the ringbarking method of control are referred to. For example, in ringbarking trees which readily regenerate their bark, as in the case of *Grevillea*, it is necessary to cut a little way into the sapwood to prevent this. If the cut is made too deep, however, the tree dies back rapidly down

to the ring, the effect being the same as felling.

The rate of depletion of the roots will vary with the season, and it is stated that deciduous trees are probably depleted most rapidly if they are ringed just after they have broken into leaf.

Some trees die slowly, even after ring-barking. It is considered that these may safely be felled one year after ringing, since the roots would be sufficiently depleted, and death would be more rapid after felling than if they were left to die after ring-barking alone. Trees which are pulled down by monkey-winch probably die more quickly than when felled. It is pointed out that all sucker growth on the trunk below the ring and from the surface roots should be rigorously suppressed.

Results of experiments are described indicating that trees growing near dead stumps in forests may have many localized lesions of Armillaria dormant in their roots, and that the fungus in these lesions may become active when the forest is felled for a plantation crop. This would explain the sudden and rapid spread of Armillaria in newly cleared forest.

Consideration is given to the question of the susceptibility of indigenous trees, and an infection experiment with twenty-six trees is described. In each species six roots had portions of infected root of *Gliricidia sepium* placed alongside. Three of the roots were cut across above the point of inoculation to simulate the effect of felling, and three were left uncut.

The results are of interest. Of the uncut roots six species were never invaded, and appear to be completely resistant; all the others were invaded, but except in two the roots limited spread of the fungus by the formation of gum barriers or callus.

In the cut roots all except two were susceptible and the fungus travelled freely in almost all. It is demonstrated therefore

that almost all species of trees found in tea districts of Nyasaland are potential hosts for *Armillaria*. To explain why only a few of these species are usually associated with *Armillaria* as a source of infection in tea estates, the author suggests that many escape infection because their roots die rapidly after felling, before *Armillaria* reaches them. Once dead and invaded by saprophytes, these quick-dying roots cannot be attacked by *Armillaria*. On the other hand, they probably form a barrier region through which *Armillaria* cannot extend.

Most dangerous as sources of infection by *Armillaria* are those trees of which the roots die slowly, e.g. *Afrormosia angolensis* (which occurs also in East Africa) and *Parinari mobola*.

To obtain the benefit of Mr. Leach's interesting results it would be necessary for the planter of such crops as tea or coffee to lay out his planting programme a few years ahead, and ringbarking operations should be commenced in time.

G.B.W.

A FIELD KEY TO THE SAVANNA GENERA AND SPECIES OF TREES, SHRUBS AND CLIMBING PLANTS OF TANGANYIKA TERRITORY: PART I, GENERA AND SOME SPECIES, by B. D. Burtt, Botanist, Tsetse Research Department, Tanganyika Territory; pp. xvi + 53; Sh. 2; The Government Printer, Dar es Salaam.

Burtt was a field botanist and collector *par excellence*, with a remarkable knowledge of the savanna plants of East Africa, and it was a great loss to East African botany when his career was cut short by the aeroplane accident in which he was killed together with his chief, C. F. M. Swynnerton, whilst on an aerial survey. The loss to botanical science is particularly great as Bernard Burtt was not one to rush into print, and his unpublished knowledge of such difficult

genera as *Acacia*, *Commiphora*, *Combretum*, and *Grewia*, some of the most important components of East African savannas, was particularly intimate.

Because the vast accumulation of knowledge of the East African flora is scattered through many botanical publications and records, only known to the specialist, there is an increasing demand for a Flora of East Africa by means of which ecologists, the technical departments and the botanically interested public can ascertain in a readily available form the names of the plants by which they are surrounded.

Bernard Burtt has attempted to supply this demand by giving in a simple way a method by which the genera and some species may be "run down" in the field without the use of either scientific language or a microscope; and he claims that no previous knowledge of botany is required, but only patience and common sense in using his field key. The materials were gathered over a period of twelve years, and he has endeavoured to put into a practical form the results of some of this knowledge obtained in the field.

The Tsetse Research Department of Tanganyika is to be congratulated on undertaking the posthumous publication of Bernard Burtt's Field Key, and the Government Printer for its attractive format and clear print. It is a useful size for the pocket, about 4 by 6 inches, and contains 69 pages of printed matter, with a few blank pages for notes at the end.

The book contains a foreword by S. Napier Bax, a preface and short bibliography, an example of how to use the key and a list of twelve warnings, the first of which says, "The field key should be used in the field and not in the house or laboratory," and another, "The mature leaf must be used and never young leaf forms." A two-and-a-half page glossary is given of the simple botanical terms. This

is followed by the key, which consists of 52 pages of matter printed only on the right-hand page, the left being blank, a most useful provision for additional notes.

To avoid disappointment, it must be realized that the key is not intended to be applicable to the Tropical Rain Forests or the Coastal Thickets, although I note that some coastal components, such as *Manilkara sulcata*, *Thespesia danis*, *Gyrocarpus asiaticus*, *Brachylaena Hutchinsii*, and *Cynometra Webberi*, are included.

It is unfortunate that the key does not always follow accepted botanical nomenclature; it contains a number of technical errors and certain specific names have been used which are no longer accepted. Also, on page 78, *Vangueria infausta* Burch. is quoted, but as this species is restricted to the Transvaal, Natal and Griqualand in South Africa, the closely allied species, *Vangueria tomentosa* Hochst., common throughout East Africa, is no doubt intended. These, however, are minor points which will not detract from the usefulness of the key, and can be corrected should another edition be called for.

As the author points out, the similarity of much of the savanna country of Northern Rhodesia, Nyasaland, Uganda and Kenya renders it possible to apply his key, with certain reservations, in these countries as well.

The book should be of value to all East Africans who are living or stationed in the savanna areas of East Africa and whose curiosity is aroused by the very varied and interesting flora with which they are surrounded. Its object will be achieved if it brings new recruits to the study of our East African flora. Despite the knowledge already gained, there are still many new plants to be discovered and many gaps have still to be filled with regard to mode of occurrence, geographical distribution, habitat, and native econ-

omic uses, the latter a branch of botany the fringe of which has only just been touched.

It is to be hoped that the second part, the specific key which was not finished at the time of Bernard Burt's death, will soon be completed by his colleagues for publication. P.J.G.

A TEXTBOOK OF AGRICULTURE, by J. G. Brash; 311 pp.; 4/6. The Sheldon Press, London, 1939.

The author, in the course of his educational work in Kenya, has found the lack of an elementary textbook on agriculture a serious drawback, both to teachers and to the taught. This work attempts to deal with agriculture on a local (Kikuyu) basis, making the subject of vital interest by introducing as far as possible the practical aspects of biology. Explanations of biological processes, in the soil and plant and animal kingdoms, are explained as simply as possible, and should be readily understandable by the African. It also introduces a system into the teaching of agriculture which should prove useful to teachers and to agricultural instructors.

As a pioneer contribution in this field it is a praiseworthy effort. There are, however, certain misleading statements which need to be corrected, and a minor criticism. On page 48, for instance, buying and keeping only pure-bred hens is cited as a method of improving native hens by breeding and selection. Also on page 50 the statement that "Just as a good bull passes on the power to milk well to the cows *with which it mates*, so a good cockerel passes on laying power to hens," is certainly a slip of the pen; the italics are mine. Another point which will not be clear to the African is the reason for the apparently contradictory methods adopted in the treatment of *boma* manure and compost. This section should be more carefully explained. L.R.D.

THE STORAGE OF FOODSTUFFS IN THE COLONIAL EMPIRE*

INTRODUCTORY

In Chapter IX of the First Report of the Committee of the Economic Advisory Council on Nutrition in the Colonial Empire consideration was given to the question of the storage and preservation of foodstuffs. In paragraphs 195 and 196 of that Report mention was made that under colonial conditions the main problems of storage are not associated with the preservation of high grade commodities for the overseas markets, but rather with the maintenance, for local consumption, of stocks from one harvest to the next, from the crops grown by the individual or community, and the preservation of perishable products in order that they may be kept for a time and, if necessary, distributed over a wider area.

The suggestion was made that steps should be taken to collect information, with a view to its subsequent circulation, regarding existing storage practices in the Colonial Empire. Much knowledge based upon experience is possessed by colonial peoples in regard to the storage of small quantities of food supplies, but nevertheless there are considerable losses in many areas as the result of faulty storing, and if practice in this respect could be improved, the general food supply position would be more favourable than it is at present. Particularly is this the case where seasonal shortfalls of food are likely to occur as the result of unfavourable weather conditions and consequent crop failures, and the question of satisfactory storage assumes added importance under war conditions when imports of food from outside sources are liable to serious reduction.[1]

In the following pages an attempt has been made to summarize available in-

formation on the subject in the hope that this may assist in focusing attention on a problem which has a considerable degree of importance under the present circumstances.

GENERAL PRINCIPLES OF STORAGE

The successful storage of foodstuffs necessitates the satisfaction of two requirements: (a) that the product to be stored, at the time of its introduction into the store, is in a condition suitable for storage, and (b) that the conditions of storage are such as to ensure that this state of affairs may be maintained satisfactorily during the period of the storage.

If stored products become invaded by insects or other destructive agencies, treatments may be available to reduce the damage, but it is far preferable to prevent loss by attention to the provision of suitable stores and to the conditions of storage.

When considering storage, foodstuffs may conveniently be classified as follows:

- (1) The grain crops, with which may be included the pulses; and
- (2) The root crops, including sweet potatoes, yams, cassava, etc.

In addition, there are products prepared from grain, such as rice, flour, brans and meals, as well as dried chips and meals prepared from root crops.

Stored grains and meals are liable to insect attack and may also be damaged by the growth of moulds and fungi if the conditions of storage are unsatisfactory, whilst they may also be attacked by rats and mice if they are not adequately protected against them.

Stored grain containing more than 15 per cent of moisture is liable to "heat" as the result of the commencement of germination and the onset of attacks by moulds and bacteria. Such grain is also

* A memorandum compiled by the Agricultural Advisers to the Secretary of State.

particularly liable to attack by weevils, since the optimum conditions for the existence of these insects in grain occur when the moisture content lies between 17 and 20 per cent. On the other hand, weevils are unable to live in grain containing less than 8 per cent of moisture, and cannot carry on active life in the absence of an adequate supply of air.

Consequently it is important to ensure that before storage the moisture content of grain be reduced to a value which will remove the liability to "heating," inhibit the growth of moulds and afford some protection against insect attack, while, during storage, conditions should provide that the moisture content of the stored grain does not increase by reason of inadequate protection. If these requirements are not satisfied loss is bound to occur; thus, experiments carried out in the Federated Malay States in 1928-30 showed that when rice is stored in bags under the conditions which normally prevail in the commercial godowns it is barely edible after eight months. On the other hand, when it is stored in bags under clean, rat-proofed and well-ventilated conditions it can be kept satisfactorily and without appreciable deterioration for a period of two years. [3]

As regards the moisture content of stored grains and meals, the factor of safety varies to some extent with different types of product, but it may be said broadly that for satisfactory storage the moisture content should not exceed 12 to 14 per cent and may with advantage be lower. Maize exported from Kenya is not permitted to have a moisture content in excess of 12.5 per cent, and if maize on receipt at Mombasa has a higher percentage it has to be reconditioned in the maize conditioning plant. This drying plant was obtained through the Crown Agents from Messrs. T. Robinson, of Rochdale, England.

The reduction of the moisture content of grain to safe levels depends to a considerable extent on climatic conditions. Where the humidity of the air is low, grain crops can be dried in the field to satisfactory moisture content. Such conditions exist in many parts of Africa. On the other hand, where the atmospheric humidity is high, drying in the field is not practicable and special measures are required to reduce the moisture content to satisfactory levels; these may take the form of drying on floors or barbecues, or even on the ground by the direct heat of the sun, the grain being spread out for the purpose and turned at intervals, provision being made to protect the grain from sudden showers of rain.

Various forms of grain-drier also exist, in which a current of heated air is forced by blowers or suction fans through the grain. The employment of such devices may add materially to the cost if the moisture to be driven off is considerable. Their use is mainly limited to places where large quantities of grain are handled and stored in bulk, and it is doubtful whether they are capable of being economically used for the handling of relatively small quantities of grain. Driers of this type were erected and operated during the last war in two West Indian Colonies and in Mauritius, and the experience there gained indicated that under those conditions the artificial drying of grain was a doubtfully economic procedure when the initial moisture is high. The maize conditioning plant operated in Kenya at Mombasa functions satisfactorily at relatively low cost, as the reduction of the moisture content of the grain before it is ready for export is generally small.

Not only must the moisture content of stored grain be reduced to a satisfactory level, but it must be kept at that level during storage, and in countries where

there is marked variation of climate between the wet and dry seasons this may prove a factor of importance. Many grains are hygroscopic and their keeping power is liable to be influenced by the atmospheric humidity at the place of storage. Difficulties in this direction are illustrated by the fact that the length of time for which rice can be stored without deterioration in Burma depends to an appreciable degree on the climatic conditions at the time it is milled, rice milled during the dry season possessing better keeping qualities than rice milled during the wet season.

Containers for the storage of grain should be dry; they should be protected from invasion of moisture from the ground and also from the entrance of moist air during wet periods, while they should also be insect-proof and ratproof.

GRAIN: BULK STORAGE

Various methods are used by the peasantry in tropical and sub-tropical countries for the storage of grain, some of which are reasonably efficient.

Provision is made, for example, by the populations in many parts of the Colonial Empire for the careful storage of their grain crops, and each homestead has its stores made of reeds or other material, carefully mudded, sometimes only on the inside but more generally on both the inside and outside walls [10]. These stores vary in size and shape, some of them being bottle-shaped and spherical, as in Meru, or beehive-shaped as in Machakos in Kenya. In certain cases the stores are raised on posts from the ground, as is common in the villages of Ceylon. In the majority of cases in Africa, the men and women own their crops individually, customs varying with different tribes, and in many areas so individual is the ownership of crops that adult members of a family keep their crops separately in different stores. In such cases the women

are expected to feed the husband and the family from the store of food in their possession, whilst the husband, though he may in cases of need supplement her stocks, uses his supplies for the preparation of beer and for the entertainment of guests. In the northern territories of the Gold Coast there is also a store of food in the keeping of the woman which is reserved for the scarcity period, and this is the last of the stores in any season to be opened. Yam producers in West Africa equally store their crops individually on wooden racks, which are shaded but exposed to the air, with the woman providing for the needs of the family and the man using his crops either for sale or for the entertainment of guests.

The grain stores are usually cleaned, and in many cases re-mudded or given a coating of cow dung, before the crop of the season is placed in them, and a considerable degree of knowledge is possessed by the people regarding the keeping qualities of the different types of grain raised. It is generally accepted, for instance, in West Africa that certain yellow-grained guinea corns keep for only short periods of time, whilst harder white-grained types can be stored without damage for lengthy periods. It is held with justification in many parts of Africa that the grain of bulrush millet (*Pennisetum typhoides*) is less liable to damage than is the grain of guinea corn, and again that the grain of *Eleusine corocana* keeps well if dry when stored and is not so seriously damaged by insects as other grains.

In the drier areas of Uganda, a striking feature of the countryside is the communal storage of grain, in which are stored considerable stocks of grain from one season to another against scarcity or famine. These communal granaries, consisting of a large number of round mudded store houses with grass-covered roofs, are well controlled and maintained, although so

far it has not been possible to introduce a satisfactory system of protection against rat damage and the accompanying danger of providing foci for the spread of plague, which is a rat-borne disease.

In Sierra Leone also it is held that rice in which ripe pods of chilli are introduced is less liable to insect damage than where this addition is not made, but whether this claim is justified has yet to be investigated.

Very fairly efficient types of granary for the bulk storage of paddy are in use among Malay rice-growers in the Malay States [5]. In the State of Kedah two types of granary occur. In their original forms they are made of plaited bamboo, but more recently galvanized iron has also been employed. They comprise a larger square type, some of which are capable of holding several thousand bushels of paddy, and a smaller round type which holds a few hundred bushels. They are erected under cover, and are raised off the ground on wooden supports which are protected by rat guards. In them paddy can be stored without depreciation for many months; if the grain is attacked, the damage is usually confined to the superficial layers. In some cases the wooden supports on which the stores have been erected are not sufficiently high and the rat guards are occasionally inadequate. Rats are known to be able to make a vertical leap of 2 feet 6 inches and to crawl around flanges which are less than 9 inches in total width. Stores to be protected adequately against rats should have their floors not less than 2 feet 9 inches from the ground and be protected at this height by flanges or pieces of kerosene or petrol tins which extend from the sides of the store or its supports for a distance of not less than 4½ inches.

In Nyasaland an attempt was made in 1931-32 with some success to develop the use of communal grain stores of a type

originally suggested by the Tanganyika Department of Agriculture. They consisted of a cylindrical mudded container standing on a mudded platform about four feet from the ground. In the final form the top was also mudded and a small manhole cut in the side for filling. It was found that in stores of this type, provided they were fumigated at the commencement of storage, grain could be kept for several months without deterioration [9].

In many parts of Africa and elsewhere, maize, after drying in the field, is stored on the cob in the unhusked condition, either in cribs or on beams, shelves or racks in houses. Cobs with tightly fitting sheaths are rarely infested. This method is satisfactory for keeping small quantities of maize for relatively short periods, but is not generally suitable for storing large quantities for any considerable length of time [2].

Various types of smaller containers have also been evolved by peasant cultivators for the storage of grain. These may take the form of earthen jars or metal containers, and petrol tins have been successfully used. In the Gold Coast maize stored in airtight petrol tins showed no loss of weight and was free from weevils after eight months, while maize stored in the husk showed a loss of 25 per cent in weight and was of less attractive appearance [2].

In India, grain stored in metal or earthenware containers has been successfully sealed and kept airtight by covering it with a layer of sand, a sheet of cloth or a piece of iron or wood being placed beneath the sand layer to prevent the grain becoming mixed with the sand [2].

Grain is often stored underground in India and elsewhere in more or less airtight pits. Experiments in Australia have shown this to be an effective method of

controlling a number of insects which infest it, the pests being killed by the carbon dioxide given off by themselves and by the grain. This method of storage may be of value where large stocks of grain have to be stored for long periods. In using it the grain should fill the available space so that the store contains as little air as possible [2].

For the large-scale bulk storage of grain the most satisfactory method is in large metal or concrete tanks, which can be hermetically sealed and which are provided with facilities for fumigation. Where, as in parts of South Africa, maize can be dried in the field down to moisture contents of 8 to 10 per cent, it can be stored in tanks with open tops without deterioration, as at these moisture values it is largely immune from insect attack. Where storage at higher moisture content has to be undertaken closed containers are necessary.

Galvanized iron containers are probably the most efficient and economical for the storage of maize. They can be constructed in sections, the sides being riveted and soldered at the joints; the lower end of each section should overlap the section below to keep out air and moisture. The tank itself should rest on a wooden or concrete platform; it is filled by means of a hole in the roof which can be hermetically closed by means of a flanged lid. Tanks of this sort are widely used in the United States of America for the farm storage of grain.

GRAIN AND MEALS: STORAGE IN BAGS IN STORES

While the bulk storage of grain is the most satisfactory method, storage in bags often has to be undertaken, and in any case bulk storage is not in general applicable to meals, flours or rice. Under these conditions special attention should be paid to the construction of the store and to the conditions of storage. Stores are

best constructed of brick or concrete, and they should at least have a concrete floor; all corners should be rounded to prevent accumulation of debris in which insects may breed, while the sides, floor and roofs should be free from cracks and openings in which insects might harbour. They should be well ventilated and should if possible have a through draught. All windows should be screened with fine mesh wire gauze, while double self-closing doors should be provided in large stores. Satisfactory ratproof granaries have been erected at Colombo in Ceylon and at Port Louis, Mauritius, for the storage of rice in bags [4].

All stores should be ratproofed, since otherwise a large amount of damage may occur, while there is also the danger of providing foci for the dissemination of rat-borne diseases, particularly plague. When grain or meals are stored in bags it is important to prevent them coming into contact with the floor. This can be achieved by stacking in rows on rafters or beams running parallel with the length of the building and allowing space for circulation of air and for inspection. In Southern Rhodesia newly bagged grain is often pigeon-hole stacked in order to hasten drying.

Maize meal does not keep well after it is ground if the germ is not removed, owing to the oil contained in the germ, which rapidly turns rancid and imparts an objectionable taste to the product. Maize meal intended for storage for any lengthy period accordingly requires to be degerminated. Machines for doing so are on the market. From a nutritional point of view, however, it is undesirable to eliminate the germ, which is rich in proteins and fats and has high nutritive value. One way of meeting the difficulty is to store maize in the form of grain and to grind small quantities as required to meet immediate demands.

PESTS AND PEST CONTROL

*Insects Attacking Stored Grains,
Flour and Meals*

Grains and their products, meals and similar materials prepared from root crops are liable to attack by a number of insects. These include the grain weevils, characterized by their long snouts, examples of which are the Grain Weevil proper (*Calandra granaria*) and the Rice Weevil (*Calandra oryzae*). The females may live for 4-5 months and lay from 100 to 200 eggs, from each of which a small grub hatches out and at once starts to feed. The grub or larval stage is passed inside the grain, and by the time the grub is fully grown the whole of the grain has been hollowed out, and in this shell pupation takes place. The time of development depends on the temperature; the lower the temperature the longer the life of the weevil, while the life period is also affected by moisture conditions and by the kind of food.

(b) The Saw-toothed Grain Beetle (*Silvanus surinamensis*), which derives its name from the presence of tooth-like projections on the lateral margins of the thorax. Both larvæ and adults feed on flour meals, nuts and seeds of several kinds.

(c) The Flour Beetles (*Tribolium* sp.), which are commonly associated with weevils in grain damaged by the latter, although they occur more commonly in flour and meals. They differ from the weevils in having no snout, and are lighter in colour and flatter bodied than the weevils, while the grub does not remain inside the grain but wanders freely through and over its food. The time of development from the egg to the adult is about forty days.

(d) Pea and bean weevils belonging to the genus *Bruchus*, short in body with thick snouts and prominent antennæ. The

larvæ are short, thick grubs, which live and complete their development within the seeds of peas and beans. The female deposits eggs on or in the seed pod and the young larvæ penetrate into the developing seed.

A number of moths also attack grain and flour, among which under tropical conditions various species of *Ephestia* (known as the Mediterranean Flour Moth), the Cacao Moth and the Fig Moth may be cited. These are less important than the weevils, but where heavy infestation has been allowed to develop considerable damage may be done.

In addition there are a number of mites which attack stored grain and foodstuffs and which, although less obvious than the beetles and the moths, occur in enormous numbers and do much damage at times.

*The Manner in which Stored Products
become Infested with Insect Pests*

Infestation of stored products by insects may occur either (a) before storage, i.e. in the field or in course of transit from the field to the store, or (b) during storage, as the result of placing them in stores which have themselves previously become infested. Infestation in the field occurs in the case of the bean and pea weevils, and it has also been shown that infestation of cacao beans by Pyralid moths originally commences on the plantation; the moths come in the night and deposit their eggs on the beans exposed on the drying platforms [6]. This type of infestation cannot be entirely prevented, but by proper precautions it may be reduced to a minimum. In Southern Rhodesia it has been established that maize in the fields is infested with weevils from various sources such as farm stores, maize stocked at railheads, shelling dumps, etc. The stores become infested by weevilly maize brought in from the fields after harvesting time.

With the liability of produce to infestation in the field it is easy to see how warehouses and granaries may become infested and lead to the infestation of produce stored therein if precautionary measures are neglected. The importance of cleanliness in barns and adjacent buildings from which insects might reach the stores accordingly cannot be too strongly emphasized.

Precautions against Infestation

The screening of windows and doors can do much to prevent pests from spreading, while good lighting, thorough ventilation and relatively low temperatures are also important, as grain moths and weevils thrive best in dark places and a still, warm atmosphere. Store rooms should be completely emptied and thoroughly cleaned at least once a year, and all emptied barrels, sacks and other containers should be sterilized before they are used again. This sterilization may be done by means of dry heat or sun, or by use of boiling water. Store rooms can be disinfected by spraying or washing the floor, ceiling and walls with kerosene emulsion, diluted carbinoleum, or similar disinfectant preparations. Whitewashing the walls and ceilings should also be regularly effected, as it assists the detection of uncleanness and the presence of destructive insects. All rubbish and refuse from the stored product should be regularly swept up and destroyed by fire, particularly from under the duckboards on which bags are stacked; the regular movement of stored material acts as a check on the multiplication of moths and weevils. Fresh material should never be stored with infested material or in storehouses or containers that are not scrupulously clean; if stores become infected to such an extent that it is in practice impossible to free them from infestation they are better destroyed.

When grain has to be stored in large quantities for a considerable period it is wise to screen it when it is received, since this has the effect of eliminating weevils before they can lay their eggs, and the danger of future infestation is minimized. The longer screening is delayed the greater will be the subsequent infestation.

The problem presented by the infestation of commodities in store is twofold, namely infestation brought in by goods introduced into the store which may be called the "incoming population", and infestation of the store itself which may be called the "resident population". Generally, the destruction of the incoming population can be more easily attained than that of the resident population. Incoming goods can be treated if necessary in special containers, but the stores with their more complex structure and almost infinite capacity for harbouring insects are more difficult to clean up. It often happens that for the treatment of incoming goods fumigation is wholly satisfactory, but for cleaning storage sheds or warehouses fumigation may be impracticable or may have to be supplemented by the use of sprays. In this connexion the following elementary precautions to prevent the spread of infestation deserve consideration:—

(1) Infested goods should be segregated. Containers, whether sacks or baskets or drums, which have carried infested goods should not be used again until disinfected or sterilized.

(2) Broken goods, screenings and sweepings are especially prone to infestation. They should be isolated and sterilized or burned at the earliest opportunity. On no account should sweepings be returned to the main store.

(3) New season's goods should never be stored with old season's goods unless these older goods are known to be clean.

(4) In inspecting goods for the presence of insects the following places should receive special attention:—

- (a) between adjacent sacks and baskets;
- (b) between these and the walls of the store;
- (c) in the ears and folds at the top of sacks and in the wicker work at the tops and bottoms of baskets;
- (d) at the highest or the darkest places in bulked goods;
- (e) on the floor and especially on the walls of stores near infested goods;
- (f) on the floors of carts, wagons or sledges used in harvesting.

Insects and mites increase in numbers only when they have an undisturbed food supply and breeding ground. Obviously, therefore, neglected heaps of old grain or meals, sweepings, old sacks, and long-accumulated debris in corners and in cracks between floorboards form ideal breeding grounds for them, and the first step in the war against these pests is to see that no such breeding grounds are allowed to remain.

The Control of Insect Pests

The main measures available for the protection of foodstuffs in store are fumigation, the use of insecticidal dusts, and perhaps the use of sticky substances to prevent the insects wandering.

Fumigation

In spite of extensive fumigation carried out in certain countries, the general principles underlying the use of fumigation are still insufficiently appreciated, and the Department of Scientific and Industrial Research has recently thought it necessary to have prepared a pamphlet dealing with the principles of fumigation, from which some of the information given below has been taken, prior to publication, by permission of the Department [11].

The first need in fumigation is the complete vaporization of the fumigant, but in warm countries this difficulty is not likely to arise. The most important cause of failure is the large amount of gas which is liable to be rendered inactive because of its absorption. This may take place on the walls of the fumigation chamber itself, on the surface of the bags, cases or boxes containing the produce, and on the surface of the produce. In consequence, ample allowance should be made for absorption of fumigant, while any fumigant so absorbed must be regarded as having little or no insecticidal effect. Further, on account of absorption of the gas by the product, the concentration of the fumigant varies inversely with the depth below the surface. Downward diffusion therefore does not depend entirely on whether the vapours of the fumigant are heavier than air, and it is essential to apply a dosage strong enough to provide a toxic concentration after the product has taken up all it can. Various products differ in their ability to absorb fumigants. Those rich in fat, such as nuts, absorb a high percentage of gas, and grain very little. Dry food will take up only traces of most gases. Accordingly, longer aeration is necessary after fumigation in the case of foods rich in fat. The concentration and the time during which a fumigant acts influence the depth of penetration of a gas. Therefore a small dosage of a fumigant for a long time is as effective as a large dosage for a short time.

A further cause of ineffective fumigation lies in the unsuitable piling or stacking of the goods to be treated, and it is necessary that in such cases goods shall be stacked so as to attain the maximum exposure to the fumigant. It has been found, for example, in experiments with cacao in bags laid horizontally that one end of every bag should be exposed. Penetration is affected also by the size and disposition of the "intergranular spaces," i.e.

the small spaces between the grains or beans. The proportion of these spaces varies greatly in different products, but is often surprisingly high. Effective circulation and distribution of a fumigant can often be attained by quite simple means; for example, by the use of large fans or punkahs slung from the roof of the chamber or building and operated from outside by means of a rope or cord.

In general, the important points to observe are that adequate dosage must be given to allow for loss by absorption and leakage, and adequate provision made for effective circulation of the fumigant throughout the goods.

One difficulty in effective fumigation is that it usually results in the absorption and retention of quantities of the fumigant in the goods treated. But this is only a drawback in that it prolongs the period of ventilation of the goods necessary before they are handled or consumed. Even with hydrogen cyanide, which is one of the most penetrating of all the fumigants, "residual" gas can in most products be eliminated by the simple process of ventilation or airing the goods.

Certain goods are quite unsuitable for treatment by fumigation, especially those rich in essential oils, e.g. cloves. But except in special instances, effective ventilation is a fairly reliable safeguard against residual fumigant.

Construction of Buildings and Containers Used for Fumigation

The first requirement for efficient fumigation is a building or container that can be made as airtight as possible, so that the fumigant shall remain in all parts of the space at full strength and for the required time. Loss of fumigant may arise from leakage and from absorption in the materials of construction. In brick and concrete buildings in good repair the ab-

sorption loss is the more important, and the total loss may be such as to render these buildings unsatisfactory for the routine fumigation of goods. Absorption can, however, be greatly reduced by painting exposed surfaces of absorbent material with oil paint, or with cellulose paint, but not with whitewash or distemper. Wood, brick, concrete, mortar, plaster and composition boards are all strongly absorptive, the capacity varying with the quality of the material, density of concrete, hardness of wood, etc.

Accordingly, wherever possible, goods should be fumigated in specially constructed fumigation chambers, and the cost of handling involved in this procedure is more than off-set by its reliability and by a saving in fumigant which is otherwise lost through leakage and absorption. Special chambers have fixed characteristics, so that the standard result is readily obtainable. They can be made of a convenient size, and should preferably be fitted with a vaporizer and with means for distributing the gas, and should be adapted to secure rapid ventilation at the end of fumigation. The use of tanks provided with a water seal is especially useful in fumigating with carbon bisulphide. The best practicable material for fumigation chambers is mild steel, which is suitable for most fumigants. It is practically non-absorptive, and lends itself to airtight constructions. A cheaper material which is often satisfactory is bituminous felt, supported on a wooden frame secured to a concrete floor. The joints must be made with a bituminous compound and the felt must be protected from mechanical damage and from contact with liquid fumigant, if this has any solvent action. Brick chambers painted with three coats of good oil paint are also satisfactory. When no proper fumigation chamber is available a water-tight barrel covered with double thickness wrapping

paper, or an ordinary bin with a properly fitting lid, sealed with paper and paste, may be effectively used for fumigation on a small scale. When no fumigation chamber is available, bags of grain or loose grain may be piled together, covered with a good tarpaulin and then fumigated. These methods give fairly satisfactory results provided the barrel or tarpaulin is gas-tight.

Fumigants Used and Conditions of Fumigation

In the Colonial Empire the choice of fumigant is restricted, and may be still more restricted in war-time. It is probable that in actual practice only two fumigants need be seriously considered—carbon bisulphide and hydrogen cyanide.

Carbon bisulphide is by far the most commonly used, although its vapours are highly inflammable and explosive when mixed with air in certain proportions; it is also noteworthy that it is not very effective against the eggs of insects, and for this reason fumigation, if efficient, should be undertaken twice, the second application being to destroy insects which may have been in the egg stage during the first fumigation. The main advantage of carbon bisulphide is that it can be used in almost any type of chamber or container. Ethylene dichloride is often employed as a substitute for carbon bisulphide when the fire hazard cannot properly be controlled. Its vapour is slightly inflammable, and both it and carbon bisulphide are frequently mixed with 25 per cent of carbon tetrachloride to reduce the risk of fire. These mixtures are, however, unstable and not satisfactory. Carbon bisulphide is applied by sprinkling evenly over the surface of the grain to be treated by means of a watering-can at the rate of from one to three gallons per 800 bushels of grain, depending upon the temperature of the grain and the tightness of the bin. If the depth of the grain in the bins is more than five feet, it is advisable to

introduce the fluid to below this depth by means of a pipe having openings at frequent intervals along its length. The use of a tarpaulin to cover the grain after the fumigant is applied will help in confining the vapour. Higher concentrations are required if the gas cannot reach the pests so easily.

It seems, however, that under war conditions some difficulty may be experienced in obtaining carbon bisulphide in colonial dependencies, since the material was usually conveyed only on foreign ships, because charges and conditions of transport on British ships were onerous. It seems certain that they will be still more onerous under war conditions.

An alternative fumigant is hydrogen cyanide. It is one of the oldest, and, when properly handled, one of the most efficient. It is, however, very dangerous to man even in small quantities if inhaled, and the strictest supervision of its use is necessary. The original method of using hydrogen cyanide was to generate it by the "pot" method from potassium cyanide and dilute sulphuric acid. This method is still employed, but is not really satisfactory for large-scale work. In temperate countries, liquid hydrogen cyanide is now widely used, but it would require special packing under tropical conditions, and its transport is difficult. The most promising form of hydrogen cyanide for tropical use consists of hydrogen cyanide absorbed on some mineral earth or on papier mâché discs. Two widely used proprietary brands of hydrogen cyanide are the fumigant known as "Zyklon," originally a German product which consists of hydrogen cyanide absorbed in an inert earth, and "Cyanogas," an American product consisting of a commercial form of calcium cyanide. It is probable that one or other of these brands and papier mâché discs may be found most suitable under colonial conditions. The gas is generated from these by simple exposure to air.

Calcium cyanide may also be employed and whilst it may have the disadvantage that the gas comes off slowly, this in turn has the advantage that the slow building up of a concentration of gas is less likely to lead to high absorption of the gas by the goods than a rapid building up of a high concentration. The substances above mentioned are easily portable, reasonably easily handled, readily measured out to give the various dosages required, and can be spread out as required to ensure good distribution of gas.

The best method of determining the conditions for fumigation is as follows:—

(1) Make a thorough survey to identify the insects completely and to find out exactly the conditions under which it will be required to kill them.

(2) Find out, by experiment if necessary, the concentration of the selected fumigant and the period of exposure required to kill them.

(3) Find out, by experiment if necessary, the amount of fumigant which must be used and the best method of application so that the requisite concentration shall be maintained at every point, in the warehouse or in the goods, where there may be an insect to be killed.

Sprays

Many storage buildings, particularly those in tropical countries, are so constructed as to render fumigation difficult. Insect infestation in such buildings is probably best tackled by means of sprays. Insecticidal sprays may be divided into two types: those which rely on a direct hit, whereby the insect is thoroughly wetted, and those which, after atomization, ultimately settle on the insects. It is only in rare circumstances that a direct hit can be obtained on stored products insects and accordingly an atomized spray is essential. A good one consists of an extract of pyrethrum carried in a white oil (kerosene).

Spraying equipment for this type of spray is available. It requires the use of an air compressor which may be driven

by a petrol engine, and particulars of the equipment are obtainable from Sterilelectric Co., Ltd., and Messrs. Charles Austen and Co., both in London.

Dusts

It is well known amongst colonial producers that seeds required for planting can be kept effectively free from insect attack if they are stored in vessels or tins with dry wood ashes. Experiments made by Squire in British Guiana have also shown that weevil damage in rice can be materially reduced by the addition of less than 1 per cent of calcium carbonate (precipitated chalk), and that in the Federated Malay States it has been found at the Government Rice Mills in Perak that the treatment of stored rice with 5 per cent slaked lime affords satisfactory protection from insect attack. In British Honduras it is a common practice to add lime when maize is stored in the cob in heaps or bins, with beneficial results.

In recent years the use of dusts for the protection particularly of grain and cereal products has become more and more general. It is unfortunate that at present no clear understanding of the action of these dusts has yet been attained, and there is considerable controversy regarding it. From the practical man's point of view, however, the main point is that these dusts are said to be surprisingly effective, and, further, the variety of mineral dusts which are effective is considerable. Of the natural mineral dusts, the best known and probably the most effective is a naturally occurring rock phosphate, widely known in Egypt under the name of "Katelsousse." This particular dust has been so generally successful that it is now marketed on behalf of the Egyptian Government by Imperial Chemical Industries Ltd., under that name.

Other effective dusts consist of pure silica, and one of these, known under the

proprietary name of "Naaki", has been widely used in Germany and elsewhere. It is a German product, and will in consequence not be available during the war. Other simple mineral dusts are precipitated chalk, slate dust and china clay. It is quite probable that a number of naturally occurring earths may prove effective. Some firms market or are about to market dusts for which they claim very high efficiency, and particulars of these can be obtained from Imperial Chemical Industries Ltd. and Messrs. Peter Spence and Co.

The use of dusts is simple, and consists merely in the mixing of the dusts with the grain or other product to be protected. Their general use is for the protection of grain and seeds, particularly pulses. It is worth noting that while experiments on the elimination of these dusts prior to milling and baking of grains are still in progress, the general opinion is that this elimination need present no difficulty, and further that many of the dusts mentioned are innocuous to the alimentary tract. Where dusts such as lime or powdered chalk are used in stored rice their elimination occurs when the rice is washed, as is customary, prior to cooking.

Of all the methods of protecting grain and seeds in particular against insect attack, it would seem that the use of dusts is much the most promising.

Sticky Bands

Many insects which affect stored products may be partially controlled, or may at least have their movements restricted, by the use of sticky substances, applied in a band to the walls or floors of storage buildings. Such substances are similar to those used for banding fruit trees. These sticky bands are of particular use when dealing with migrating caterpillars. They are also of use in isolating infested piles of goods. For such purpose the bands may be applied to the floor.

It is important to remember that in dusty buildings the surfaces of the bands will rapidly become coated and may thus allow insects to pass over without becoming trapped. Care should be taken to ensure that the sticky surface is maintained in a fresh condition.

Commercial forms of adhesive for grease-banding of trees and banding of warehouse walls are available, but it is quite probable that birdlime may be readily procured or made. The making and use of it is prohibited in some countries for birdliming, but doubtless knowledge of its manufacture and use still persists.

THE STORAGE OF ROOT CROPS

The storage of tropical root crops in a fresh condition is a more difficult problem than the storage of grain, owing to the large amount of water they contain. There is a marked difference, however, in the case of storage of different kinds of produce. Thus yams are comparatively easy to store, while it is practically impossible to store cassava satisfactorily for any length of time once the roots have been dug.

The most satisfactory method of storage of sweet potatoes and cassava, when the preservation of considerable quantities of such products is involved, is to slice them and to convert them into dried chips. Slicing into pieces about half an inch thick, with or without peeling, and drying the slices in the sun by exposure on a drying floor is a common practice in parts of Africa. The process presents no difficulty, except that the slices require to be protected from rain during drying, since if they are wetted they are liable to become leathery and an unsatisfactory product results. Chipped or sliced root crops can be stored in the same way as dried grains, and the same precautions require to be observed, as they are

equally liable to become damaged by insect attack or mould growth.

Yams

For storage in a fresh condition it is important that the tubers should be fully ripe before they are lifted. They are ready for digging when the foliage has become dry. So long as dry weather persists the tubers can be left in the ground, as is common in parts of West Africa, and lifted as required for consumption, but the usual practice is to harvest the yam crop as soon as it is ripe. The tubers should be dug very carefully so as to avoid bruising, as bruised tubers do not store well. After lifting, the tubers should be left exposed to the air for a few hours and then stored on shelves in a well-ventilated and cool shaded room or store in layers three or four feet deep. Yams are also stored in carefully packed heaps within weather-proof buildings and sometimes in pits. The latter method cannot, however, be recommended unless the soil is thoroughly dry and likely to remain so.

Buds and eyes should be removed as soon as they show signs of sprouting, while bruised tubers are liable to attack by moulds and if not removed they should be treated with slaked lime to prevent spread of infection. Under all conditions of storage, yams require to be regularly inspected to ensure the removal of all diseased tubers, otherwise infection will spread rapidly, resulting in considerable loss. Under favourable conditions yams can be held in storage for several months, some varieties being much more suitable for lengthy periods of storage than others.

Cassava

Cassava roots do not store well for any length of time after they have been removed from the ground. Under certain climatic conditions it is dangerous to attempt to do so. The crop can, however,

particularly in dry areas, be allowed to remain in the ground for several months before deterioration sets in, and the most satisfactory method of storing in a fresh condition is to allow the crop to remain in the ground, digging supplies as required for immediate consumption. Certain varieties of cassava can be left undug for much longer periods than others without undue detriment to the starch content of the tuberous roots.

Cassava lends itself very well to the preparation of dried chips, and if for any reason it is impracticable to leave the crop in the ground this is the best procedure. In wet districts or in areas liable to insufficient drainage, cassava cannot be satisfactorily left undug, and if production is in excess of consumption needs, the surplus should be converted into chips or meal. When the chips are required for use they may be pounded and sieved to remove the fibre from the meal.

Cassava meal may also be prepared directly from the fresh cassava, as is the usual practice amongst the aboriginal Indians in British Guiana and the Mayas in British Honduras. In the former colony the roots are cleaned and then grated upon what resembles an English grater which has been beaten out flat and nailed to a small piece of board. The resulting meal is then stuffed into a basket-like cylinder which has loops attached to either end. One of these loops is attached to a beam in the house, whilst through the lower loop is passed a stout stick which is pulled upon so that the wicker cylinder, owing to the pressure, gradually becomes longer and longer. The watery contents so expressed are collected and boiled to form the cassareap which is used for the preservation of meat. The meal remaining in the cylinder is then taken out and rubbed through a sifter. It is then either dried in the sun or baked into thin

cakes on large flat iron plates. Cassava meal and cakes form an important item of the diet of the Indian tribes of tropical South America.

Sweet Potatoes

Considerable attention has been given to the storage of sweet potatoes in the United States of America, and a technique of storage which has apparently given satisfactory results has been evolved there [7]. The essential points of the process are a preliminary curing process of ten days to two weeks duration at a temperature of 80° to 85° F., followed by storage in specially constructed stores at a temperature of 55° F. Such conditions are, however, unattainable under normal conditions in the tropics. Various methods have been attempted under tropical conditions, and storage in pits or clamps has on the whole given the best results. In some recent trials in Barbados the clamps were prepared by digging out the soil to make a shallow circular depression 3 to 4 inches deep and about 3 feet in diameter. The potatoes were stacked in this in a conical heap. The heap of potatoes was then covered with trash and a layer of soil placed over the trash. This method of storage was considered to be very successful and to be quite practicable in areas where pests affecting sweet potato tubers are not prevalent [8].

Results in Trinidad have also shown that under suitable conditions sweet potatoes can be stored in this way for about two months in fairly good condition, with a loss in weight of about 15 per cent.

Some varieties keep very much better than others, and it is generally held that the red-skinned types are to be preferred for storage to the white or yellow skinned types. The sweet potato known in Trinidad as Black Rock has a reputation for storage purposes.

In storing sweet potatoes care must be taken to protect the skin from injury by bruising or cutting, as the skin is very delicate and if it sustains injury decay spreads rapidly.

ACKNOWLEDGMENTS

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SOME RESULTS FROM BUKALASA EXPERIMENT STATION

PART I—GENERAL

By G. W. Nye, B.Sc., Dip. Agric. (Wye), Senior Botanist, Department of Agriculture, Uganda

As the cultivation of cotton gradually increased in Uganda the necessity for experimental work on cotton became evident, and money was made available for the establishment of Cotton Seed Selection Stations. Serere was selected for the Eastern area and Bukalasa for Buganda. In 1919 land was purchased at Bukalasa in Bulemezi County from the Mailo owner, Mr. Shem Spire. Bukalasa is situated in the middle of Bulemezi County, and consists of typical elephant grass country with fertile brownish-red top soil overlying red subsoil, except on the hill top which is stony and unfit for cultivation. In the old days Kabaka Mwanda had a country residence on the hill, and the site of his hut is still visible. The area originally purchased was 299.9 acres, but a further 90 acres were purchased from the same owner in 1933 in order to provide land for the segregated main increase plot of cotton. The original intention was to provide "a cotton seed selection farm for Buganda," but no experimental work was conducted at Bukalasa until 1924, when an agricultural officer was stationed there to carry out small experiments on cotton. Experimental work on cotton, food crops, etc., was extended gradually, and various plantation crops, such as tea, coffee, and cinchona, were tried unsuccessfully. By 1927 a fairly comprehensive experimental programme was in being. In 1929 an additional agricultural officer was appointed for agricultural education, and in 1930 the Senior Botanist was transferred from Serere to carry on cotton breeding work for the elephant grass areas. No further changes took place until

1939, when the botanical work was transferred to the new central station at Kawanda.

ROTATIONS, METHODS OF CULTIVATION, ETC.

From 1927, green manuring was used to restore fertility, but experience and the results of various experiments have shown that green manuring seldom has any beneficial effect at Bukalasa, and, further, it is difficult to fit it in as a catch crop in a normal rotation. In 1934 it was decided to use elephant grass as the fallow crop, and this has been used with considerable success since then. The general rotation now practised is:—

1st year	.. Cotton (early planted).
2nd year	.. Food crops (groundnuts, simsim, etc.), Cotton (late planted).
3rd year	.. Cotton (early planted and inter- planted with beans and/or ground- nuts).
4th year	.. Planted with elephant grass.
5th and 6th years	Elephant grass.

This rotation is maintaining fertility and reduces erosion to a minimum. An experiment has been laid down to find out the minimum period for the elephant grass fallow.

In the early days, cultivation followed native practice and was by hand. It was found impossible to keep cattle owing to the biting fly, *Stomoxys*, which is particularly prevalent in elephant grass areas. Donkeys were tried for ploughing, but were unsuccessful, and hand cultivation has been general except for the larger plots, which are cultivated by caterpillar tractor. Intercultivation has always been by hand. An interesting point arose some time ago when it was obvious that the

cotton crop at Bukalasa was definitely poorer in appearance and yield than in nearby native plots. The reason for this was obscure until, acting on a suggestion from native cultivators, the number of intercultivations was cut down by half. This comparatively "dirty farming" was the correct solution, and the cotton at Bukalasa is now at least as good as, and generally better than, that on native plots.

The land at Bukalasa is on slopes typical of Buganda, and measures to prevent soil erosion are essential. Valuable surface soil has been lost, but the fallow periods under elephant grass, and contour bunds, are assisting in restoring slowly the lost fertility and in preventing any further erosion. Excellent yields of all crops are now being obtained, and it is obvious that the balance of fertility is being more than maintained. The three-year fallow period under elephant grass is undoubtedly the solution of the problem in Buganda, as long as land is available in sufficient quantity to allow for 50 per cent to be locked up under fallow, but pressure of population and/or increase of land under cultivation in the future make it essential for other methods to be investigated. One of the smallholdings (which has been run as an educational holding) is to be used to investigate the possibilities of mixed farming.

THE MODEL SHAMBA

In 1927 a demonstration holding was established to be run by a Muganda and his wife. The underlying idea was to find out what acreage a family could cultivate and what profits were likely to be made.

The site selected for the holding was on poor soil, and although it is comparatively level, erosion has occurred, and recently small contour bunds have been constructed. The cropping has been continuous, and two crops are taken off each plot

annually, except that once every four years a spring crop of *Crotalaria juncea* is grown as a green manure, which is dug in before the following cotton crop.

Changes have been made at various times, both in the size of the holding and in the rotations. For instance, maize was originally included as an economic crop, but as it has little economic value in Bulemezi one of the two maize crops has been omitted, thereby allowing for all four economic plots to be under cotton every year. As simsim proved uneconomic on this soil it has now been omitted from the rotation, and early-sown cotton replaces simsim, followed by late-sown cotton.

The holding is divided into four sections:—

House and banana garden, $1\frac{1}{2}$ acres.

Four plots of $\frac{1}{2}$ acre each for economic crops.

Four plots of $\frac{1}{4}$ acre each for food crops for home consumption.

One small coffee plot of 55 trees.

The following rotations are practised:

	Economic crops	Food crops
1st year	Groundnuts followed by cotton.	Beans followed by cassava (short period).
2nd year	Green manure (<i>Crotalaria juncea</i>), followed by cotton	Cassava (from 1st year) followed by green manure.
3rd year	Maize followed by cotton.	Groundnuts followed by sweet potatoes.
4th year	Early planted cotton interplanted with beans.	Sweet potatoes (from 3rd year) cowpeas.

Coffee was first planted in 1932 and began to crop in 1936.

The total area of the holding is 4.5 acres, and it has been found well within the capacity of a man and his wife to carry on all the cultivation except that at busy times, as for instances when the green manure has to be dug in, it becomes necessary to employ hired labour.

The following figures show the money expended by the holder on hired labour for the last six seasons:—

1932-3 ..	Sh. 31/68	1936-7 ..	Sh. 38/94 (includes
1933-4 ..	Sh. 2/64		Sh. 27/72 for
1934-5 ..	Sh. 11/88		mulching coffee)
1935-6 ..	Sh. 12/54	1937-8 ..	Sh. 22/50

(In 1937-38 the tenant was working on his own without his wife and consequently more labour had to be hired.)

The banana garden has shown signs of serious deterioration, and is now too poor to support the family with plantains. Under native practice it would have been abandoned and planted elsewhere some time ago. The soil on the rest of the holding has every appearance of deterioration and it is now very light and sandy, typical of over-cultivated Buganda soil. It appears to have very little organic matter, and is now in a condition liable to severe sheet erosion. Bunds have been made, and these are proving effective.

The results of experiments with green manures at Bukalasa have been conflicting, but in general no effect has occurred on either the crop immediately following or on subsequent crops. On this holding, however, green manuring does seem to have had a considerable effect on the yield of cotton, as the following figures show:

YIELDS PER ACRE (LB.)

Season	Cotton after green manure	Cotton after ground-nuts	Cotton after maize	Cotton after simsim	Early cotton
1932-3	450	—	352	520	—
1933-4	427	—	199	289	—
1934-5	712	—	496	490	—
1936-7	414	260	340	184	—
1937-8	512	230	270	—	460

Thus in every season since 1933-34 cotton has given higher yields after green manure than after the other crops.

The yields of cotton show a tendency to decrease. The increase in 1937-38 is mainly due to the fact that the closer spacing of 3 ft. x 1 ft. was employed and an early planted plot of cotton was included for the first time.

The following tables summarize the results to date:—

Year	Cash return after deducting cost of hired labour	Total acreage	Return per acre	* Annual acreage under economic crops only	* Return per acre of economic crops
	Sh.	Acre	Sh. cts.	Acre	Sh. cts.
1927-8	56	3	18 70	1.25	15 00
1928-9	149	3	49 70	1.25	39 60
1929-30	115	4	28 80	2.0	14 40
1930-1	122	4	30 50	2.3	15 00
1931-2	102	4	25 50	2.3	12 50
1932-3	104	4.5	23 10	3.5	7 50
1933-4	83	4.5	18 50	3.5	5 30
1934-5	136	4.5	30 20	3.5	8 60
1935-6	142	4.5	31 60	3.6	8 90
1936-7	108	4.5	24 10	3.1	8 00
1937-8	112	4.5	24 90	3.1	8 30†

*The acreage includes spring and autumn crops; thus half-acre of groundnuts followed by half-acre of cotton is counted as one-acre of economic crops for the season.

†Simsim and cotton replaced by early cotton.

The price of cotton has a large bearing on the net cash return. For instance, the price in 1929-30 was Sh. 19 per 100 lb., compared with Sh. 9/50 in 1937-38. The average return is fairly satisfactory, but after payment of taxes, etc., the average sum available for the holder is only Sh. 70 per year, which cannot be looked upon as a very good return for a year's work; but it has to be taken into account that his family's food has cost him nothing except his own labour, so that he is still better off than a porter earning Sh. 12 a month, and in addition he is independent.

The following table gives yields per acre of the economic crops:—

Season	Cotton	Simsim	Groundnuts
	Lb.	Lb.	Lb.
1927-8 ..	?	188	?
1928-9 ..	615	174	60
1929-30 ..	608	180	?
1930-1 ..	380	189	1,035
1931-2 ..	200	135	378
1932-3 ..	414	80	338
1933-4 ..	305	48	726*
1934-5 ..	566	204	1,090
1935-6 ..	433	438	1,822
1936-7 ..	306	48	1,618
1937-8 ..	368	—	890†
1938-9 ..	Over 400	—	1,098
Mean ..	419.5	178.4	915.3

*Groundnuts spaced at 1' x 1' for first time.

†Simsim omitted from rotation.

COFFEE

Bukalasa is only about ten miles south of the northern limit of Robusta cultivation in Buganda, but as there is a considerable and increasing area of native-grown Robusta in Bulemezi, it was considered necessary to lay down experiments in methods of cultivation at Bukalasa. Previous to 1929, attempts had been made to establish Robusta at Bukalasa, but for reasons unknown these were unsuccessful. In 1929 the first replicated experiment was established and consisted of the following treatments: Clean weeding versus permanent cover crop (*Centrosema pubescens*), and no shade, banana shade and *Gliricidia* shade. The lay-out was a 6 x 6 latin square, with 40 trees per plot, spaced at 10 ft. x 10 ft. The coffee was grown on the modified multiple stem system, which gave three bearing stems with a fourth sucker allowed to come away when the first three began to bear, to act as a replacement when the first stem was cut back. This was found to be unsatisfactory, as it resulted in a very etiolated and poor-yielding replacement stem; the system was therefore changed and no suckers are allowed to grow until the tree is stumped, when one sucker is then allowed to come away for each stem removed. This system is proving satisfactory, provided that the tree is not allowed to become too unhealthy before it is stumped.

It was found in practice very difficult to maintain the bananas as shade; in fact, they are gradually dying out, which confirms native experience. *Gliricidia* as a shade tree has proved to be very unsatisfactory, as it needs constant attention, and it is almost impossible to train it to produce any reasonable amount of shade; further, it harbours mealy bug, which drops from the trees on to the coffee bushes. It would be a most unsuitable shade for native cultivators in this

country. The first cycle of this experiment ended between 1937 and 1938, when a big stumping programme was necessary; thus, after four seasons which showed biennial cropping, with a fifth giving a higher yield than the fourth, there is now a considerable drop in yield which will remain low until the stumped plots have fully recovered.

The results to date show that the coffee without shade has yielded better than under either banana or *Gliricidia* shade. Clean weeding has given an increased yield over the permanent cover crop, but recently there have been indications that the plots with a permanent cover are improving as compared with the clean-weeded plots. The combination of bananas and permanent cover has had a definite depressing effect on the yield of the coffee. Clean weeding has done better than would be expected under field conditions, as the comparatively small size of the plots prevents serious soil erosion.

Some interesting interactions have shown up: for instance, cropping is most regular under the *Gliricidia* shade, which would be expected, but it is more irregular under bananas than with no shade at all. The interaction of ground treatment and seasons is significant, the clean-weeded plots yielding more regularly than those under cover crop for the first five seasons.

The following tables summarize the results:—

YIELDS IN TONS OF FRESH CHERRY PER ACRE

	No shade		Banana shade		<i>Gliricidia</i> shade		Mean
	Clean weeding	Cover crop	Clean weeding	Cover crop	Clean weeding	Cover crop	
1932-3 ..	3.91	2.04	3.04	1.58	3.22	2.10	2.65
1933-4 ..	6.04	6.16	6.00	4.97	4.71	5.44	5.55
1934-5 ..	3.34	2.70	3.52	2.70	3.31	3.10	3.11
1935-6 ..	3.90	4.06	3.92	3.31	3.78	4.07	3.84
1936-7 ..	5.18	5.10	4.37	4.01	4.21	4.16	4.50
1937-8 ..	2.15	2.41	1.60	1.96	2.21	2.28	2.10
Totals ..	24.52	22.47	22.45	18.53	21.44	21.15	21.76

TOTAL OF SIX SEASONS
TONS OF FRESH CHERRY PER ACRE

	No shade	Banana shade	<i>Gliricidia</i> shade	Total
Clean weeding	24.52	22.45	21.44	68.41
Cover crop ..	22.47	18.53	21.15	62.15
Total ..	46.99	40.98	42.59	130.56

In 1932 a second experiment was laid down to include mulching with elephant grass. A 4 x 4 latin square consisting of 50 plants each at 10 ft. x 10 ft. was planted, with the following ground treatments: Clean weeding, mulching, permanent cover (*Centrosema*), and weed cover (grasses removed). The whole experiment is unshaded. Mulching has been done annually to a depth of one foot, and has cost approximately Sh. 60 per acre. The permanent cover of *Centrosema* has gradually been replaced naturally by indigenous plants which give as satisfactory a cover as the originally planted crop.

The results to date are tabulated below:—

TONS OF FRESH CHERRY PER ACRE

Season	Clean weeding	Mulch	Weed cover	Per- manent cover crop	Mean
1934-5	1.48	1.53	0.39	0.47	0.97
1935-6	5.28	5.13	1.00	2.02	3.36
1936-7	3.89	5.66	3.22	3.79	4.14
1937-8	5.91	6.25	3.02	4.18	4.84
Totals	16.56	18.57	7.63	10.46	—

The statistical analysis shows that the differences between mulch and clean weeding are not significant, but both are significantly better than weed cover and cover crop, while cover crop is significantly better than weed cover.

The effect of the mulch is most marked, particularly during the dry season, when

the leaf-fall is noticeably less than with the other treatments. The weed cover plots are in a deplorable state, and will become progressively worse. They form a fine example to native growers of the folly of allowing weeds to grow freely in their coffee. The increased yield due to mulching is not very considerable to date, and with the present low price for Robusta coffee mulching is hardly a paying proposition. On the other hand, the hidden profits of mulching, such as soil conservation and the reduction in weeding costs (which has considerable appeal to native cultivators), make it well worth while. The best recommendation at the present time is undoubtedly alternate-row mulching.

A third experiment was started in 1934 which consisted to some extent of a repetition of some of the previous treatments, but these were included in order to be able to compare them with new treatments. The various treatments are as follows: Shade (*Gliricidia*) versus no shade, with four ground treatments: clean weeding, full mulch, alternate row mulch, and a cover crop from October to March. Further, half of every sub-plot receives a petrol tin full of rotted cotton seed per tree every year, the other halves of the plots being controls. The experiment is blocked, with sub-blocks for shade and no shade, with a total of 80 sub-plots. The experiment is further complicated by having eight progenies at random in each plot, each row being a different progeny. The coffee has made excellent progress, and a very large crop is being harvested at the time of writing. Only two years' results are available, and although no conclusions can be drawn as yet, the yields are given below, as they are of interest:—

YIELDS IN TONS OF WET CHERRY PER ACRE

	Irrespective of ground treatments		Irrespective of shade and cotton seed				Irrespective of other treatments		Mean
	<i>Gloria</i>	No shade	Clean weeding	Full mulch	Alternate row mulch	October-March cover	Cotton seed	No cotton seed	
1936-7..	0.36	0.43	0.43	0.44	0.35	0.36	0.50	0.29	0.39
1937-8..	1.65	1.69	2.03	1.26	1.73	1.66	1.91	1.44	1.67
Total ..	2.01	2.12	2.46	1.70	2.08	2.02	2.41	1.73	2.06

In both seasons the increased yield due to the application of cotton seed was significant.

In the second season the mulched coffee gave a significantly lower yield than the clean-weeded, the most likely explanation of this being that the mulching is reducing the tendency to overbear.

The coffee in this experiment has recently suffered from leaf crinkling, and counts of plants so affected have confirmed that the condition is closely correlated with lack of shade. It appears, moreover, to have some genetical significance, as there is considerable variation in attack between progenies; for instance, progeny 288A 3F, with 28 per cent affected plants, has significantly more than any of the other seven varieties.

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NOTES ON PYRETHRUM DRIERS

By Gilbert Walker, Nakuru, Kenya Colony

The "Ainabkoi" system of drying pyrethrum flowers, developed by Mr. R. O. Barnes, and described in the *East African Agricultural Journal* (No. 4, Vol. II, Jan. 1937), has been adopted by many growers, including the writer, and a description of two labour-saving methods of lowering the trays may be of interest. As is now well known, the flowers are spread evenly on trays which are slid on to rails one above the other, like drawers into compartments, and the hot air filters vertically upwards through the trays (six to eight in number) by natural draught. When the contents of the lowest tray are dry the tray is taken out, all the others are pulled out and replaced one rung lower, and a fresh tray loaded with green flowers is slid into the space left vacant at the top.

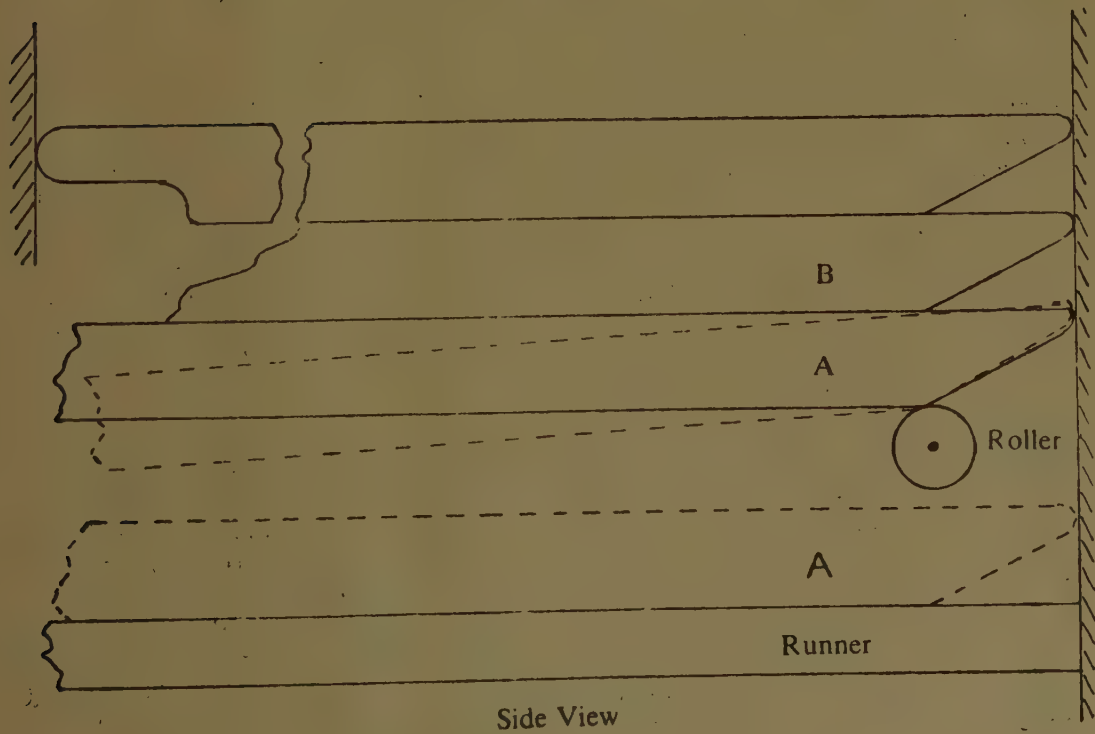
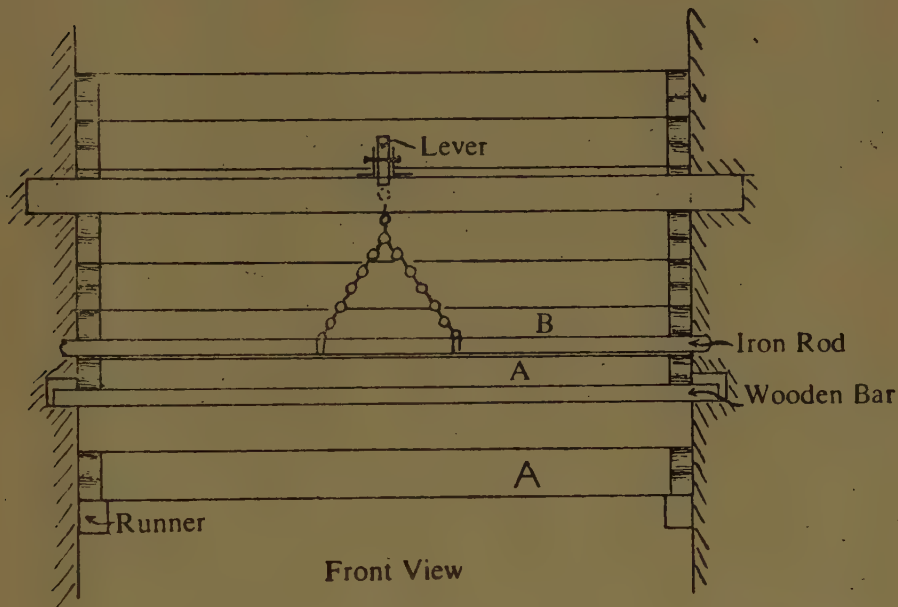
The advantages are that (1) the hot air filtering upwards comes into intimate contact with the flowers and cannot escape without doing its work; (2) the process, being a continuous one, results in the flowers being taken out as soon as they are dry, contrasting with the various systems of "batch" drying in which a drying chamber is loaded with green flowers at a convenient hour one day and unloaded the following day, in spite of the fact that the trays cannot be made to dry at an even rate and that the many which dry in eight or nine hours have to remain in the heat for a further twelve hours or more and are thereby liable to suffer damage; (3) the green flowers are put in at the furthest distance from the source of heat and meet with the comparatively cool, partly saturated, air which has come up through the lower trays, and this, as is recognized in the drying of fruit, is the best way of causing the moisture to be given up without risk of casehardening.

The disadvantages of the Ainabkoi are its rather greater initial cost and the considerable labour involved in lowering the trays when the dry ones are taken out at the bottom.

After several attempts to remove the latter objection there has been adopted on this farm a device which is simple to operate and foolproof, a description of which may be of interest to pyrethrum growers.

The trays have to be rather better built than is usual, and are made of 3 in. by 1½ in. light timber, such as Mkeo or imported deal, and are conveniently 7 ft. 6 in. to 10 ft. long by the usual 3 ft. wide. The sides of the trays project beyond the ends a matter of 5 in. At the far end the projecting ends are cut sloping upwards, the actual end being left about ¾ in. thick and rounded as shown in the sketch. A slope of 2 to 1 has been found satisfactory. The other ends are rounded and cut as shown.

Rails are dispensed with, and the trays are stacked one on the top of the other. The sloped ends of the lowest tray rest on a pair of small rollers, 2½ in. in diameter and 3 in. long, the point of contact being where the slope begins. The rollers can be made of hard wood, and the sections of roller belonging to one of the makes of lawn mowers are admirably suited; already bored with a half-inch hole, they are strung on an iron rod which is fixed across the end of the compartment at the correct position near the back and 5 in. above two runners (2 in. by 2 in. hard-wood) nailed horizontally, one to each side, at the base of the compartment. There is thus a space into which a tray can be slid along the runners and below the rollers.



The front ends of the lowest tray are carried by a 1 in. by 1 in. movable wooden bar resting crosswise on supports at each side of the compartment.

Before the lowest tray can be moved, the weight of the front end of the stack of trays above it must be taken, and this is done by a lever of flat iron, 1 in. by $\frac{1}{2}$ in., working on a fulcrum (a $\frac{3}{8}$ in. pin) set on a wooden crosspiece. The short arm of the lever is 4 in. long and drilled at the end with a hole from which is hung horizontally by means of a light chain a $\frac{3}{4}$ in. iron rod long enough to reach across both ends of the tray. In order to save the operating end of the lever from projecting awkwardly, it is only some 4 in. long, and a piece of piping 20 in. long can be slipped over it as a handle which serves as well for the other compartments of the drier.

When the lowest tray (A), the front end of which rests on the wooden bar has to be removed, the iron rod is slipped under the ends of the bottom tray but one (B). By means of the lever, B with the stack of trays above it is raised half an inch, A is grasped, the wooden bar removed, the end of A lowered to rest on the runners, and the wooden bar replaced. Tray A is now lying with its back end still on the rollers but with its near end on the runners as shown in dotted lines in the sketch, and it will be seen that its only point of contact with tray B is where the bevel begins. Weight and friction are largely eliminated and the sloping back end tends to slip off the rollers out towards the operator, and a slight pull enables A to be removed. As it comes out, the back end of B descends until it rests itself on the rollers.

Tray A is pulled out until it can be seen if the flowers are dry, and if not it is pushed in again along the runners beneath the rollers for the further period of time necessary. The front end of tray B is lowered by the lever until it rests on

the wooden bar, and the operation is completed by sliding in a tray of fresh flowers on the top of the stack.

It is necessary to have two attendants in a drier for handling trays, loading, unloading, bagging flowers, and stoking the furnace, and although this description is a long one, they can easily between them remove the bottom tray and lower the stack in a few seconds.

On pulling a tray off the rollers it will have a few inches to fall on to the runners. This fall can be readily prevented by cutting out a short piece from the runner and pivoting it at one-third of its length on a pin, so that it swings upright. The short end takes the tray as it slips off the roller. On sliding the tray in again the piece of wood swings over horizontally out of the way.

If it found that air escapes between the trays the whole of the ends can be boxed in and a piece of board used to fill the spaces where the trays are put in and taken out.

There is another method of lowering the trays in an Ainabkoi drier without pulling them out. While not so labour-saving as the system with the rollers, yet it will appeal to many growers by reason of its simplicity and low cost. It was worked out by Mr. H. G. Colquhoun, of Nakuru.

The cost of the building is reduced because the compartments, instead of being 3 ft. wide by 10 ft. deep are 6 ft. wide by 9 ft. deep, so that only about half the number of compartments need be built. A compartment contains three trays, 6 ft. by 3 ft., inserted sideways on rails instead of the usual two trays, 5 ft. by 3 ft., or one tray, 10 ft. by 3 ft., inserted endwise.

The wooden rails, 3 in. by 2 in., except for one pair of runners fixed at the bottom, are loose, and their ends project

through vertical slots in the back wall, where they rest on pegs at the proper spacing. At the front, which is closed by hanging doors, they rest on pegs let into the sides of the compartment.

When the lowest layer of three trays which rest on the fixed runners is dry, all three trays are pulled out with a crook, then the pegs in front which support the lowest pair of loose rails are taken out one at a time, the ends of the rails let down by hand till they rest on the fixed runners and the pegs are pushed into their holes again. Then the pegs next above are taken out, their rails let down, the pegs re-inserted, and so on. The back ends of the rails are treated in the same way, and the trays have now all been lowered one rung. The lowest rails which are lying on the runners are then pulled out through the slots in the back wall, and as this takes place their three trays slip off and are left on the runners.

The pair of rails are then pushed in at the top through the back wall, and three fresh trays are slid on to them through the doorway at the front. Small shutters or sacking can be used to block up the spaces in the slots through the back wall.

It will be seen that the operation of lowering trays consists in pulling out the pegs and replacing them.

An advantage is that any sort of cheap tray can be used, and since the trays are put in sidewise instead of endwise the loading floor need only be large enough to accommodate a tray 3 ft. wide instead of one 5 ft. or 10 ft. long. It is, however, necessary for the operator to be able to get round to the back of the building in order to work the pegs at that end and to pull out and re-insert the rails, so that a covered passage is desirable.

Mr. Colquhoun now seeks to effect an improvement by doing away with the pegs, except the lowest ones. The rails will then lie directly on the trays beneath them, and the stack will be lowered by means of a lever, taking the weight at each corner alternately, the pegs being removed and replaced as is done in the case of the wooden bar of the roller system first described. This will quicken the work.

These methods of lowering trays, either by loose rails or by rollers, have so greatly simplified the operation of the Ainabkoi that growers will no longer hesitate to adopt this type of drier on the score of cost or of labour.

It would be interesting to learn whether any still simpler way of working the trays has been discovered.

Two thousand years ago an unusual farmer boy lived in northern Italy. That young chap was aware of much of the hidden and practical ways of nature, especially those that are close to the land. Virgil recorded many of his observations of natural phenomena in those classics known as the "Georgics". He protested against the senseless waste of natural resources. He sought to teach that there is dignity in labor upon the soil, and that there is strength and happiness to be found in a closeness to nature. He was a

mighty good farmer. Listen, for instance, to a bit of his advice regarding the utilization of land as it is told in the first "Georgic":—

But ere we stir the unbroken ground,
The various course of seasons must be
found;
The weather and the setting of the winds—
The culture suiting to the several kinds
Of seeds and plants, and what will thrive
and rise,
And what the genius of the soil denies.

Prof. Raymond J. Pool in *Science*.

REJUVENATION OF A COFFEE PLANTATION IN THE BELGIAN CONGO*

By R. Dupret

The rejuvenation of coffee plantations is an important matter at the present time in the Belgian Congo. Two main factors are involved:—

1. The necessity of keeping the existing areas planted with coffee, in view of the restriction placed on plantations of coffee in the Congo.
2. The necessity of directing attention to intensive culture, to reduce the net cost and the labour required in comparison with the quantity of coffee.

In all projects for the Congo one ought to consider labour requirements not only by the hectare but in terms of the yield of coffee. Thus one might say: 1 hectare of coffee requires $1\frac{1}{2}$ men for extensive culture and 2 for intensive. Too much stress is laid on the number of hectares and not enough on the number of kilograms yielded. The example of the East Indies in this connexion should serve as a guide.

As a lead towards intensive culture we shall describe here two methods of rejuvenation that tend towards this goal:—

- (1) Periodical rejuvenation.
- (2) Perpetual rejuvenation.

Periodical Rejuvenation.—Consists in postponing the rejuvenation of a block of coffee until it shows the first signs of exhaustion. If after a certain number of years, say ten, it is noticed that certain plantations are not producing enough, holes 2 ft. square and 2 ft. deep are dug in quincunx pattern between the coffee trees, immediately after the bad harvest. These holes will then be filled one after the other with prunings and weeds. If possible, compost made from pulp, cotton seed, etc., will be added.

The coffee trees, profiting by this aeration and fertilization, will give two or three good harvests. At the beginning of the year following the preparation of the

holes they will already be filled with material that will have formed humus. Let us suppose that the holes are dug in 1940, at the beginning of the rainy season. In 1941 the holes will be filled with humus and young coffee trees planted in them. Thereafter for two years the old coffee trees are still kept; the young trees are topped and their primaries nipped off if they develop too strongly.

In the third year, i.e. in 1943, after the picking, the old coffee trees are removed and the plantation is entirely composed of new young trees, three years old, selected for big bean, without a stoppage having occurred in production.

Instead of removing the old coffee trees completely one can stump them, and thus arrive at the method that we do not recommend so strongly, namely—

Perpetual Rejuvenation.—The old coffee trees, which we will call A, are stumped; the young ones, B, will be three years old and in production. After six years B are stumped; A, stumped three years before, are producing; after nine years, A are stumped, and so on.

This method can be applied on especially good soils. Also, the two methods can be combined; that is to say, one can stump once and replace once: remove old trees, manure the ground, and replant.

The expensive part of the "periodical rejuvenation" lies in the establishment of nurseries of first quality; the making of the holes is largely paid for by the increased production of the old coffee trees, which are the first to profit by it; the filling of holes takes place automatically, actually facilitating maintenance work.

Thus, at the cost of a nursery, one has a completely rejuvenated and improved plantation, and there will have been no stoppage of production.

* *Agriculture et Élevage au Congo Belge*, 12, p. 130, 1938. Translation by R. E. Moreau.

NOTES ON ANIMAL DISEASES

Compiled by the Department of Veterinary Services, Kenya Colony

VI—BLUETONGUE

Bluetongue is a specific non-contagious transmissible disease of sheep caused by a virus. It is characterized by inflammation of the mouth and tongue, the upper respiratory passages, the intestines, and the sensitive parts of the hoofs, and it is usually accompanied by a more or less marked febrile constitutional disturbance. The presence of a bluish discoloration or cyanosis of the inflamed tongue has given rise to the name by which the disease is generally known, but it should perhaps be mentioned here that this feature is often absent in mild cases. It is known that undoubted cases of bluetongue may show no obvious symptoms beyond a mild febrile attack followed by debility and some loss of wool. Cases of this nature are referred to by farmers as simply "fever" and are usually regarded as distinct from bluetongue, yet it has been possible to recover the virus of bluetongue from these "fever" cases.

EPIDEMIOLOGY

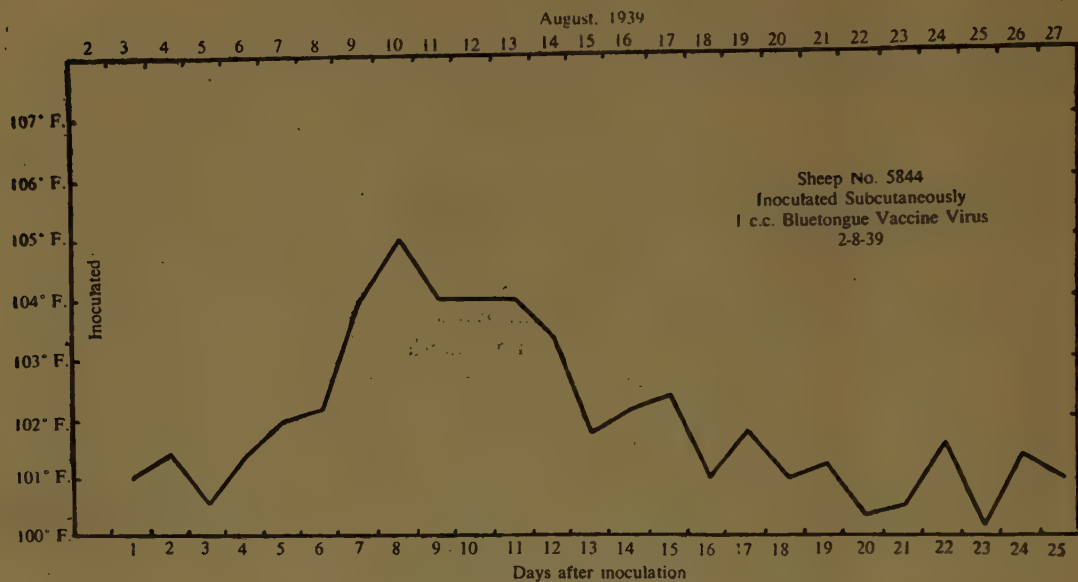
Bluetongue does not appear to the same extent every year. The occurrence and the virulence of the disease seem to be governed to a large extent by climatic conditions. Bluetongue is essentially a disease of the wet season, and the first outbreaks usually coincide with the onset of the rains. The disease is more prevalent in wet years than in dry. In years of drought it may fail to make its appearance at all. The rainfall also seems to exert a marked influence on the character of outbreaks, for in wet years the disease appears to be more virulent, whereas in dry years it is more often milder in type. The disease is more commonly met with

in low-lying areas than at high altitudes, although as Spreull in South Africa pointed out long ago it is the relative local elevation and not the absolute height above sea-level that determines outbreaks. The incidence of bluetongue is highest in damp swampy places, around dams and lakes and in the vicinity of rivers and valleys. In practice, farmers take advantage of this knowledge to prevent the disease or to control the spread of an outbreak by moving the sheep from marshy areas to higher grazing grounds. The observation that simple movement of infected flocks from lower to higher ground is sufficient to control the spread of the disease has also given rise, at least in part, to the view, now generally accepted, that bluetongue is an insect-borne disease.

In Kenya the bluetongue season may be regarded as lasting from about the beginning of November up to the end of April, but from what has been said above it will be understood that this period is subject to considerable variation, depending upon the rainfall in any given year.

NATURAL TRANSMISSION

Up to the present time the manner in which bluetongue is transmitted in nature has not been elucidated. All the available evidence, based upon wide observations both in the field and in the laboratory, strongly suggests that the vector is a nocturnal biting insect. There is, however, no experimental proof of this and therefore the problem of the natural transmission of bluetongue still remains unsolved.



SYMPTOMATOLOGY

The period of incubation of bluetongue under natural conditions has not so far been determined. Experimentally it has been found to vary considerably. It may be as short as one day or as long as ten days, but more commonly it varies from four to seven days.

The onset of bluetongue is marked by fever which generally lasts from about five to seven days. The chart above is a typical temperature chart showing the bluetongue fever reaction that follows the subcutaneous inoculation of a dose of bluetongue vaccine virus.

Early in the course of the disease the sick animals stop feeding and ruminating and exhibit peculiar licking movements of the tongue. As the disease progresses the animals become dull, lie down frequently, and show some loss of condition. During the febrile stage of the disease there is great thirst, which in later stages is sometimes accompanied by vomiting.

A short time after the commencement of the temperature reaction the mucous membranes of the mouth and tongue, as also the skin over the lips and nose, become inflamed and assume a distinct rosy colour. At the same time the skin over the entire body may become similarly flushed. This is followed by œdematous infiltration and swelling of the lips, particularly the upper lip. At this stage there is usually some slight lachrymation, frothing at the mouth, and a discharge from the nose. The nasal discharge, at first catarrhal in nature, soon becomes muco-hæmorrhagic, and when this dries it forms a thick incrustation over the nostrils which sometimes causes difficulty in breathing.

In severe cases there is also œdema and swelling of the tongue and dental pad, accompanied by œdematous infiltration and swelling of the lower part of the face and neck.

Minute hæmorrhages now begin to appear on the mucous membranes of the mouth, lips, tongue, dental pad, and cheeks. This is soon followed by the appearance of localized excoriations of the mucous membranes, more especially those of the lips and tongue. The mouth is now painful and the injured mucosa bleeds readily on handling. It is at this stage that the typical bluish or purplish discoloration of the tongue and mucous membrane of the mouth becomes evident.

From about the ninth to the twelfth day after the onset of the febrile reaction, symptoms of lameness begin to appear. The claws are hot and tender on pressure and there is a bluish or red line around the coronary bands. The gait of the foot-sore sheep is characteristic, and has been likened to that of a foundered horse. As a rule, lameness persists only for a few days, but during this time the sick sheep lie down frequently, refuse to feed, and lose condition rapidly. Towards the end of the reaction period there is sometimes partial or complete shedding of the wool. In the later stages of the disease, particularly if the inflammation of the sensitive parts of the hoofs is severe, the affected animals gradually become weaker and weaker, and finally death supervenes from debility and exhaustion.

COURSE

Clinically it is possible to recognize the following stages in the course of the disease: At first there is a rise in temperature. This is followed in a day or two by swelling of the lips and redness of the buccal mucous membrane. Minute hæmorrhages now begin to appear and these soon give place to localized excoriations of the mucous membranes. By this time the temperature has returned to normal and symptoms of coronitis develop.

Death or recovery may supervene at any stage in the course of the disease. Thus it is possible to distinguish various clinical forms of bluetongue:—

(1) The *abortive* form is characterized by a more or less marked febrile reaction and slight reddening of the buccal mucous membrane, followed by recovery.

(2) The *peracute* form, in which the reaction is accompanied by redness and petechiation of the mucous membrane of the mouth. This form may terminate in either death or recovery.

(3) The *acute* form, where, in addition to redness and petechiation of the buccal mucous membrane, there appear excoriations on the lips, mouth and tongue. This form may also terminate in either death or recovery.

(4) The *subacute* form is characterized by the development of coronitis and debility from which the affected animals may die.

There is no true chronic form of the disease, although death more often occurs from debility brought on by an acute or subacute attack of bluetongue than at a stage when the characteristic symptoms of the disease are at their height.

MORTALITY

Mortality from bluetongue varies considerably from year to year. In dry seasons it may be as low as 5 per cent; at other times it may be as high as 30 to 40 per cent of all sick sheep. As a rule, however, the losses from actual deaths from bluetongue are not severe. Nevertheless, the economic loss to the farmer resulting from the great loss of condition of the affected flock may be great. In addition, there is considerable loss of wool through partial or complete casting of the fleece. More rarely losses may be experienced from abortion in pregnant ewes.

POST-MORTEM LESIONS

In typical cases of bluetongue, that is to say in animals that have died from an acute or subacute attack of the disease, the following principal changes may be noted:—

Skin.—The skin over the lips and nose is usually hyperæmic. In addition, there is often a reddish or bluish ring at the base of the horns and around the coronary bands and in some cases the skin over the entire body may show diffuse reddening.

Mouth.—There is nearly always some frothing at the mouth which on examination shows excoriations on the lips, the gums and the cheeks, together with more or less extensive sloughing of the epithelium of the tongue.

Stomach.—The rumen and the reticulum sometimes show hæmorrhagic patches, whilst the abomasum is usually the seat of an acute gastritis. The mucous membrane of the true stomach may be diffusely inflamed and thickened, or it may have a peppered appearance from the presence on its surface of innumerable scattered hæmorrhages. More rarely ulceration of mucosa may be present.

Intestines.—The small and large intestines may show diffuse or patchy inflammation, with some thickening of the lining membrane.

Spleen.—The spleen is usually enlarged.

Liver.—The liver is congested and sometimes slightly icteric.

Kidneys.—These organs are congested and some cases exhibit well-marked hæmorrhagic infiltration of the cortical zone.

Respiratory System.—A discharge from the nose is nearly always present. This may be thin and watery or thicker in

consistency and muco-hæmorrhagic. There may be an excess of fluid in the chest cavity, and the lungs may show a well-marked apical œdema. The heart sac often contains a quantity of fluid and the heart itself usually shows distinct sub-endocardial hæmorrhages in the left ventricle.

Lymphatic System.—The lymph glands throughout the body may be more or less inflamed, œdematous and swollen.

Whilst the above-described changes are usually present in typical cases of the disease, it should be remembered that in old standing cases of bluetongue death frequently supervenes from debility at a time when the characteristic lesions of the disease have healed. In such cases all that a post-mortem examination reveals is an extremely pale and emaciated carcass with perhaps some evidence of casting of the fleece and occasionally pulmonary œdema and degeneration of the heart muscle.

DIAGNOSIS

The diagnostic lesions of bluetongue are those which are found in the mouth. When buccal lesions are associated with symptoms of fever, rapid loss of condition and lameness, differential diagnosis from the better-known diseases of sheep in Kenya Colony offers no difficulty. It sometimes happens, however, that the only animals available for post-mortem examination are old standing cases of the disease that have died from debility at a time when the pathognomonic lesions of bluetongue have disappeared. In such cases a consideration of the locality in which the sheep are grazing, the season of the year, and the general history of the outbreak may assist in arriving at a diagnosis, but it is often necessary to resort to inoculation methods before the true nature of the disease is discovered.

PREVENTION

Whilst there are several methods based upon the epidemiology of the disease of protecting sheep against bluetongue—for example, moving the flock from low, marshy areas to high, dry ground; housing the flock at night and in the early morning; dipping susceptible sheep in carbolic acid or coal tar derivative dips and allowing the sheep to remain unshorn during the bluetongue season—preventive inoculation is the most reliable method of combating the disease. It is now recognized that annual vaccination affords a sure protection against a severe attack of bluetongue. Vaccination consists in the inoculation of a dose of attenuated bluetongue vaccine virus. The dose of the vaccine is 1 c.c., given subcutaneously, by the usual sterile technique. The febrile reaction produced by the inoculation lasts from about the seventh to the thirteenth day after vaccination, during which time mild clinical symptoms of bluetongue may become noticeable. More severe reactions may be expected in sheep in poor condition. These should be culled, isolated near food and water, and not driven with the remainder of the flock.

SPECIAL WARNINGS

Bluetongue vaccination should be carried out:—

- (1) In advance of the rains which mark the onset of the bluetongue season, otherwise a natural attack of the disease may complicate vaccination.
- (2) At least three weeks before shearing.

Bluetongue vaccination should not be carried out:—

- (1) In wet weather.
- (2) When sheep are in poor condition, either from drought or from worm infestation.
- (3) When sheep are recovering from other diseases; for example, Nairobi sheep disease, heartwater, etc.

Pregnant ewes should not be treated, and lambs of from six weeks to six months of age should receive one half dose of vaccine. Rams should not be castrated whilst undergoing a reaction to bluetongue, and castrated animals should not be inoculated until such time as the scrotal wounds have healed.

Finally, sheep should not be dipped during the reaction or convalescent periods.

NOTE

South African workers have described a disease of cattle which appears to be identical with bluetongue of sheep. The mouth lesions may be confused with those of foot-and-mouth disease, and for this reason the disease is popularly termed pseudo foot-and-mouth disease. Other symptoms and lesions of this cattle disease are similar to those of bluetongue of sheep, and in doubtful cases the diagnosis may be confirmed by inoculation of susceptible sheep. In Kenya, bluetongue virus has from time to time been recovered from cattle, but it has never been possible to assign to the virus with any degree of certainty the causation of a definite illness in cattle.

CAN SEEDS OF EUROPEAN VEGETABLES BE PRODUCED SUCCESSFULLY IN THE TROPICS?

It is the common practice in tropical countries to import from temperate regions all seed requirements of European vegetables, because it is generally assumed that such seeds cannot be produced successfully in the tropics. Three of the reasons given for this assumption are: (1) the suppression in the plant of sexual processes due to such factors as high temperatures, the too-short tropical day or the lack of a resting period; (2) the lack of vigour in the resulting seed; and (3) the gradual degeneration of the progeny grown from seeds produced in the tropics. The evidence that seeds of certain European vegetables can be produced in the tropical highlands and the comparatively recent development of varieties bred for lowland tropical conditions must lead one to question this old assumption that the tropical regions are intrinsically unsuitable for the production of seed of all European vegetables. Past failures may have been due, in part, to lack of the necessary knowledge of plant selection or to faulty methods of drying and storing.

With a view to obtaining all the available information on the subject, the Imperial Bureau of Horticulture and Plantation Crops was asked whether the seed of such vegetables as cabbage, carrot, lettuce, onion, etc., were produced successfully in commercial quantities anywhere in the tropics, and whether there was any reason why seed of such vegetables should not be produced successfully in the cool highlands of East Africa. The Bureau reported that very little was known on the subject, and then kindly undertook to approach agricultural authorities in eight tropical countries with a view to obtaining what information was available. The relevant information contained in the very helpful replies received,

added to that obtained from the East African Agricultural Departments, is summarized below and forms the main basis of this note, which has been expanded to embrace other European vegetables not mentioned in my original query.

British Guiana.

Annuals such as lettuce and tomatoes produce viable seed quite readily, but the progeny after the first or second generation degenerates as regards both size and quality. Biennials are uncertain in the matter of seed production. Small cultivators may use locally produced seed for several sowings. Onions are of special importance, and seed of the Bermuda or Teneriffe type is imported annually from the Canary Islands. The small Indian onion varieties will produce seed, but these kinds produce no bulb and are used only for seasoning.

Hawaii

Seeds of lettuce and tomatoes can be produced successfully. Seeds of other vegetables are imported.

India

India produces seed of cauliflower varieties suited to lowland tropical conditions, while seedsmen's catalogues offer various lines of Indian-raised seed, including carrot, onion, peas and radish.

Java

Seed is normally imported. However, it is recorded that at elevations of 3,000 ft. to 5,400 ft. seed of the following has been raised under small-scale experimental conditions, the results being satisfactory: Beans (French ?), broad beans, carrot, cauliflower, endive, lettuce, peas, and tomatoes.

Kenya (five replies)

No. 1.—At 5,500 ft. approximately. Reports that in most cases acclimatized

seed gave better crops and germination was higher. Has dealt in country-bred seeds for many years and successfully raised seed of asparagus, beans, cabbage (var. Sugarloaf only, which does not appear to deteriorate after several generations), cucumber, lettuce (improves generation after generation, if properly rogued), onion (improves with every generation), peas (now on 7th generation of Alderman, Greenfeast and Earlicrop; weekly inspection and roguing always essential), radish, spinach, turnip, and tomato. Unsuccessful or only partly successful with brussels sprouts, beetroot, carrot, leek, parsley, and parsnip. At a lower elevation the third generation of own cauliflower selection is being raised.

No. 2.—At 5,000 ft. approximately. Good seed produced of beans, lettuce, peas, and tomato.

No. 3.—At 5,500 ft. approximately. Seed of the following produced successfully: asparagus, aubergine, beans (broad, French, and runner), carrot, cucurbits, globe artichoke, leek, lettuce, onion (variety of Australian origin), parsley (good, but gets coarse), peas (Alderman best), and tomato. Unsuccessful or only partly successful with beetroot, cabbage, cauliflower, radish, and spinach beet.

No. 4.—At 6,200 ft. Reports success in raising seed of beans, beetroot (in moist and shaded situation), cauliflower (when planted in March), chicory and endive, leek (planted in February, seeded in December), lettuce (when planted in August), peas, radish, spinach and tomato.

No. 5.—At 5,500 ft. approximately. Reports success in seeding the following when rainfall is sufficient: asparagus, beans, beet, all cabbage family, carrot, celery, cucumbers (the Telegraph type need to be artificially pollinated), endive, kohlrabi, leeks, lettuce, peas (early roguing essential), parsley, radish, spinach, tomato, and turnips.

Malaya

At Cameron Highlands (4,800 ft.) beans (dwarf and broad), peas, spinach, and tomatoes raised from locally grown seed have been grown successfully for several generations without deterioration, or in some cases with slight improvement. No effort has been made, however, to become self-supporting in this respect. Seeds have been imported in the past from many sources, and the evidence points to the fact that country of origin is not of prime importance but is only a convenient source of supply of a suitable variety.

Philippine Islands

Seed of the following is produced: beans, chinese pea, cucurbits, lettuce (to some extent), mustard, radish, shallot, and tomatoes. Other seeds are imported from U.S.A., China, India, and Canary Islands.

Puerto Rico

Practically all seed requirements of cool-weather vegetables are imported from U.S.A. Evidence indicates that seed of warm-season vegetables can be successfully raised between about sea-level and 3,000 ft.

Tanganyika

The successful production of the following reported from the Southern Highlands, any deterioration observed being put down to lack of proper selection: beet, cabbage, cauliflower, lettuce, onion, and turnip. Onion seed is successfully produced by Africans on Kilimanjaro at approximately 4,000 ft. Runner beans observed producing seed at Arusha (unusual in the tropics).

Trinidad

Seed of beans, cucurbits, and peas is commonly saved by local inhabitants without apparent deterioration. Vegetables such as cabbage, carrot, cauliflower, lettuce, and onions, seed of which is imported, would be flowering and fruiting in the wet season, when mildews would play havoc with them.

Uganda

Amongst the vegetables reported as seeding are lettuce and peas (in Kigezi highlands, where it is an important crop).

From an examination of the evidence it appears that no fundamental research work has been done on the problem set at the beginning of this note but, as the tabulated summary shows, in all the tropical countries mentioned seed of some European vegetables can be produced. The East African highlands have evidently special advantages. They can produce seed of more kinds of cold-weather vegetables than any other of the countries named; they are, in fact, the only tropical region reporting seed production of asparagus, beet, cabbage, celery, globe artichoke, kohlrabi, leek, parsley, parsnip, radish, runner bean, and turnip. The varying experiences recorded by Kenya growers living within comparatively short distances of one another (between 5,000 and 5,500 ft.) indicate the variations, presumably due to differences in rainfall, soil and other natural conditions, that can be expected between districts. This may be an advantage rather than a disadvantage, as in practice seed-raising is a specialized business where each grower

usually confines himself to one or two lines best suited to his particular soil and climate.

From an examination of the evidence obtained, it appears that there is no reason why seed of many European vegetables should not be successfully produced in the tropics, particularly in the highland regions.

The replies provide no acceptable evidence for or against the belief that degeneration takes place in European vegetable varieties grown from seed produced in the tropics. Lengthy experiments would be needed to settle this point, and in the course of carrying them out it is probable that new varieties, more suited to tropical conditions, would be obtained as the result of re-selection, so that some of the end-products might differ considerably from the original experimental material. The success of Indian seedsmen in producing tropical varieties of cauliflower—the most fastidious and exacting of the cabbage family—and the adaptability of the Iceberg and Mignonette varieties of lettuce to tropical conditions are a foretaste of the development that can be expected in time.

A.G.H.

SUMMARY

	Artichoke, Globe	Asparagus	Beans, dwarf	Beans, broad	Beans, runner	Beet	Cabbage	Carrot	Cauliflower	Celery	Chicory and endive	Cucurbits	Kohlrabi	Leek	Lettuce	Mustard	Onion	Parsley	Parsnip	Peas	Peas, chinese	Radish	Shallot	Spinach*	Tomatoes	Turnip
Hawaii ..	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
India ..	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Jaya (h'lands)	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Kenya :																										
No. 1 : 5,500'	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
No. 2 : 5,000'	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
No. 3 : 5,500'	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
No. 4 : 6,200'	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
No. 5 : 5,500'	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Malaya (h'lands)	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Philippine Is.	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Tanganyika ..	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Trinidad ..	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Uganda ..	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+

*Kinds not stated.

PYRETHRUM BREEDING

Mr. H. C. Thorpe's progress report under this heading, which appeared in the March number of the Journal (pp. 364-368), will no doubt have been read with much interest. There is reason to suppose that the results will prove of practical value, and it is unfortunate that, through an editorial oversight, the section in which Mr. Thorpe emphasized this point was not printed. It now appears below, together with a summary of the whole article.—ED.

Once free-flowering lines of high toxicity have been isolated, they can be multiplied by root division and issued to farmers for planting. As previously stated, such material will be available in limited quantities in 1940. In Kenya, pyrethrum is, like other species of *Chrysanthemum*, self-sterile, and it will be necessary on this account to plant more than one line in order to obtain the mixed population that is necessary to ensure adequate fertilization and subsequent development of the achenes or fruits in which the pyrethrins are situated. This has been amply emphasized by Beckley (1938), and a further warning is given here. The planting up of mixed splits will, however, present no serious practical problem.

It has been suggested that successive splitting of the parent plant might lead to a gradual reduction in pyrethrin content. Experiments are now in progress to test this, but should it prove to be so, planting of new acreages will have to be by seedlings and not by splits. The whole position with regard to the planting of seedlings and splits needs clarification. Seedlings appear to be more desirable from the agricultural viewpoint on account of their greater drought resistance, a fact which this season has amply served to emphasize. Splits flower earlier, but do not yield the same financial return in the long run.

From the viewpoint of the plant breeder, the planting of seedling material raised by the farmer from his own seed suffers from the disadvantage, as pointed out earlier, that it is inefficient, being a mixture of types of varying toxicity. The male parent in such cases will always be

unknown, and splits and seed of however good an initial quality will produce plants of an inferior pyrethrin content, due to outcrossing with poorer types.

The deterioration of high-content lines may be circumvented by the establishment of a nursery, well away from other pyrethrum, in which proven seed can be produced from high-test parents which have been shown by analysis to pass on their high toxicity to their progeny. Farmers would then not save seed from their own planting, risking the possibility of a deterioration in toxicity, but would obtain it direct from the nursery for each new planting.

Such a nursery is already in existence at the Plant Breeding Station, Njoro. This year's work will show whether the high-test parent strains pass on their pyrethrin content to their offspring. If this is found to be so, small quantities of seed will be available for distribution to farmers in 1940.

A good start has been made with all these projects, and the establishment of pyrethrum fields composed of splits derived from clones of high toxicity or from seedlings from proven high-test mother plants should be possible in the very near future.

SUMMARY

Pyrethrum is a crop of very mixed genetic character, due to self-incompatibility and enforced outcrossing. Great variation between individual plants has been found, in Kenya and elsewhere, for characters such as resistance to lodging, flower size, growth habit and pyrethrin content. Pyrethrin content has been found

elsewhere to be an inherited character, but influenced by environment. Findings in Kenya support the view that pyrethrin content is inherited.

A programme of breeding work is in progress, including the isolation and propagation of high-test strains for issue

to farmers. A plant analysing 2.44 per cent pyrethrins has been found. A nursery for the production of seed from high-test mother plants has been established.

The method of inducing polyploidy by the use of colchicine may have value in breeding work with pyrethrum.

DEMONSTRATION FARMS

There remains another aspect of agricultural research, and that is the question of farm practice; for, unless the best use is made of the findings of science in the byre and on the field, of what avail the findings? It is in this connexion, in my view, that we have the weakest link in the chain. To translate science in terms of farm practice demands out and out research and a vast deal of field experimentation. But little State-aided research is being undertaken in farm practice with a view to the discovery of entirely new methods of farming—new rotations and the like—this is left almost wholly to the practical man. When we think of research we immediately think in terms of subjects and what we please to call the subjects of science—agricultural chemistry, agricultural botany, agricultural economics, and we forget agriculture as such, which has not even yet been elevated to the rank of a research subject. This, to a large extent, has been due to the professional snobbishness which seems to be inseparable from narrow specialization, and it has undoubtedly also been due to an over-concentration on the problems of individual crops considered as independent units.

We hear much of the need for demonstration farms. In fact, most of the farms of the farm institutes and of the agricultural departments are demonstration farms—and good demonstration farms at that, frequently run at a profit. I question whether such farms are neces-

sary—the best privately farmed farm in every district is usually the best demonstration farm of all. The need is for experimental farms, research farms, mad farms! Farms where discoveries in the arts of farming are being made, where new rotations are being invented, where entirely new schemes of farming are being evolved, for that is what science necessarily implies, if the facts of science are to be brought fully to bear on the practices of farming. Until we have an agricultural research station as opposed to stations devoted to the sciences, I see little hope of science contributing in full measure to the evolution of the new agriculture. The more progressive of the agricultural departments and of the farm institutes might, however, do much in this direction if they could break away from the canons of good husbandry and regard themselves less as demonstrators and more as experimenters, and if a creditable balance sheet was not deemed to be a prime necessity and the chief criterion of able management. To-day the canons of good husbandry built of the centuries are all but dead; agriculture, like everything else, is in a state of flux. There is very little to demonstrate and everything to find out. A spirit of adventure and an ability to change with the times is what agricultural education and research must endeavour to transmit to the rising generation of farmers.

Prof. R. G. Stapledon, *The Land Now and To-morrow*.

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